# The Oxwelder's Handbook

## Instructions for Welding and Cutting by the Oxy-Acetylene Process

15th Edition


THE LINDE AIR PRODUCTS COMPANY

*Unit of Union Carbide and Carbon Corporation*

New York and Principal Cities

*In Canada:*—Dominion Oxygen Company, Limited, Toronto

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## CHAPTER 1

# Development of Oxy-Acetylene Welding and Cutting

IN view of the present almost universal use of oxy-acetylene welding and cutting it is difficult to realize that the entire commercial development of the oxy-acetylene process has taken place within the last thirty years.

The experimental basis for the development of the oxy-acetylene process was the discovery by Le Chatelier, a French chemist, in 1895, that the combustion of oxygen and an equal volume of acetylene produced a flame having a temperature far higher than that of any gas flame previously known. In a paper read before the Academie des Sciences on the temperature of flame he described the properties of the oxy-acetylene flame and called attention to the important fact that the primary combustion of equal volumes of acetylene and oxygen yields hydrogen and carbon monoxide, both of which are non-oxidizing in character. These gases then burn in the outer envelope of the flame, uniting with oxygen from the surrounding air to form the final products of combustion, water vapor and carbon dioxide.

By a most interesting coincidence, work was progressing almost simultaneously in different parts of the world on two other processes which were destined to insure the commercial success of the oxy-acetylene process. In May, 1892, Morehead and Willson at Spray, N. C., had demonstrated the feasibility of the commercial production of calcium carbide, the material from which acetylene gas is produced. In Germany in May, 1895, Dr. Carl von Linde placed in operation a machine for the production of liquid air, which was the forerunner of the present process for the manufacture of commercial oxygen. It seems almost paradoxical to record that the bringing together of the results of these two investigations—the one at the extremely high temperature of the electric furnace, the other

at the unbelievably low temperature of liquid air—should yield a process which can unite or sever metals with equal facility.

## EARLY DEVELOPMENT OF THE PROCESS

Le Chatelier's paper attracted the attention of other investigators and many experiments were made to devise suitable blowpipes which would permit the control of the oxy-acetylene flame necessary for its application in welding. In 1901 blowpipes of a practical type were introduced by Fouché and Picard and by 1903 the process began to be used industrially. As experience was acquired, the foundation was laid for the technique necessary in welding the various metals. It soon became evident that full advantage of the new process could not be taken until supplies of oxygen and acetylene became available in economical and convenient form. Oxygen was at first produced chemically by a process which was merely an adaptation on a larger scale of the familiar laboratory experiments. Gradually the idea developed of compressing oxygen into steel cylinders which provided a convenient means of transporting a supply of oxygen to any desired location.

By this time acetylene was coming into use for house lighting and, as would be quite natural to expect, attempts were made to parallel the experience with oxygen by providing cylinders of compressed acetylene for welding. Before long it became evident that this was not advisable because of the endothermic character of acetylene, a property which has made necessary the enactment of regulations prohibiting the generation, storing or use of free acetylene at pressures exceeding 15 lb. per sq. in. After much study, the problem of providing a safe means for transporting acetylene under pressure was solved by constructing a cylinder packed full of porous material, the pores then being filled with acetone, a liquid chemical having the property of dissolving many times its own volume of acetylene. This paved the way for the modern dissolved acetylene industry.

With this preliminary review as a background, it will be of interest to outline the development of the oxy-acetylene industry in the United States.

## CALCIUM CARBIDE AND ACETYLENE

About the year 1889, Major James T. Morehead, a cotton manufacturer owning a mill at Spray, N. C., became interested in the idea of transforming his excess water power into electrical energy and began experimenting with electric furnaces for making new metallurgical products. In 1891 he organized the Willson Aluminum Company to develop Thomas L. Willson's proposed method for obtaining aluminum by heating a mixture of aluminum oxide and carbon in an electric furnace. Failure to obtain aluminum directly led to the suggestion that metallic calcium might be produced first and this used as a reducing agent to produce aluminum.

On May 2, 1892, the electric furnace was charged with a mixture of lime and carbon. As the product obtained was crystalline, somewhat metallic in appearance, and gave off gas in contact with water it was concluded that metallic calcium had been produced. When the gas was lighted, however, it

**Fig. 1. Tapping molten calcium carbide into chill cars.**

burned with a smoky flame which at once indicated that it was not hydrogen, which would result from the action of water on metallic calcium, as this gas burns with an almost colorless flame. Upon chemical analysis, it was found that the gas was acetylene and that the product of the furnace was calcium carbide. This was the first time that calcium carbide had been

produced on a scale large enough to warrant commercial consideration.

After further investigation, which included the development of a type of electric furnace that would permit continuous operation, the Union Carbide Company was organized in 1898 for the manufacture and sale of calcium carbide. A large plant was built at Niagara Falls, utilizing the hydro-electric power which had just become available at that point and an experimental plant at Sault Ste. Marie, Mich., was subsequently enlarged when the hydro-electric power development there became a reality. By the year 1904 these two plants were in operation with a capacity sufficient to supply the entire demand for carbide in the United States.

Further improvements in manufacturing methods led to the development of huge tapping furnaces which replaced the less economical smaller units originally used.

During this early period of growth, the uses for acetylene developed along three principal lines: house lighting, miners' lamps and automobile lighting. Various types of generators were required to produce acetylene gas from calcium carbide and in 1901 Union Carbide Company organized a subsidiary, the Acetylene Apparatus Manufacturing Company, to manufacture generators and other acetylene apparatus. When, about 1910, it became evident that the new industry of oxy-acetylene welding would offer a new and important outlet for acetylene, Oxweld Acetylene Company was organized to take over the business of the Acetylene Apparatus Manufacturing Company and in addition to engage in the manufacture and sale of oxy-acetylene equipment.

### DISSOLVED ACETYLENE

In the meantime, the method of distributing dissolved acetylene in cylinders mentioned previously, was being developed commercially by The Prest-O-Lite Company, Inc., organized in 1904, at Indianapolis. At first dissolved acetylene was used principally for automobile lighting but as the oxy-acetylene process began to attract attention, it was realized that dissolved acetylene was ideally suited for use with this process, and larger types of cylinders were developed to provide a convenient, portable source of acetylene for welding and cutting.

## OXYGEN

In Germany in 1902, Dr. Carl von Linde operated his first machine for the commercial production of oxygen from liquid air. This was a direct result of his earlier work on liquid air, referred to above. At first the commercial demand for oxygen was small, being limited to hospitals and a few specialized uses

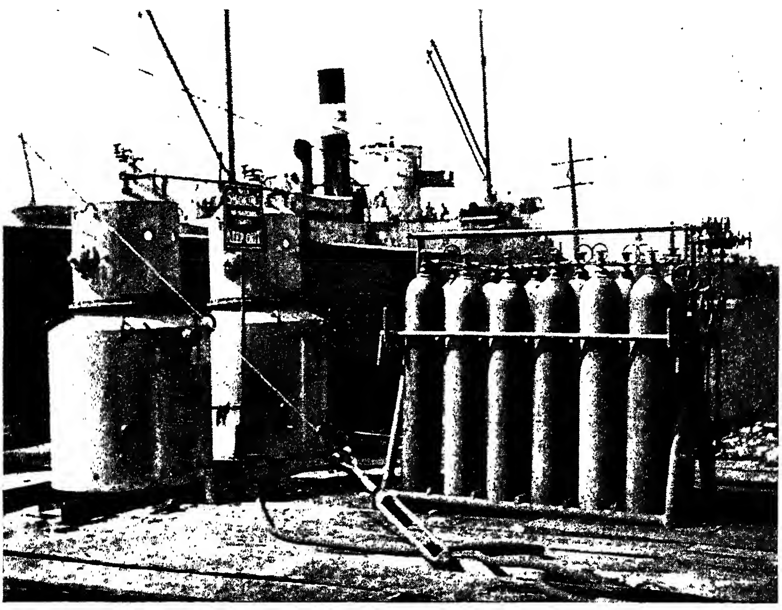


Fig. 2. Acetylene generators (left) and manifolded oxygen cylinders (right) for large scale operations.

in industrial work. Here again the oxy-acetylene process opened up a promising market, and as the process began to be used industrially the demand for oxygen increased at a rapid rate.

In 1907, The Linde Air Products Company was formed to acquire the American rights to the Linde processes and in this same year the first plant in the United States to produce oxygen by the liquid air process was placed in operation at Buffalo, N. Y. In 1909, the capacity of the Buffalo plant was doubled and a plant was built in the Chicago district. Other plants

were added in rapid succession until today The Linde Air Products Company has oxygen plants located at important industrial centers throughout the country and supplemented by a chain of distributing stations so that oxygen is readily obtainable at any point.

As a natural result of its interest in developing the use of oxygen for oxy-acetylene welding and cutting, The Linde Air Products Company introduced welding and cutting blowpipes of the Fouché type as well as other oxy-acetylene apparatus. In 1912, the Union Carbide Company secured a substantial interest in The Linde Air Products Company and the manufacture and development of oxy-acetylene apparatus was turned over to Oxweld Acetylene Company. This company proceeded to develop a complete line of stationary and portable acetylene generators, welding and cutting blowpipes, regulators, welding rod and many other items.

In Nov. 1917, formation of Union Carbide and Carbon Corporation brought together a group of companies having related interests. Important units in this merger were Union Carbide Company, The Linde Air Products Company, The Prest-O-Lite Company, Inc., and Oxweld Acetylene Company. Each unit had been a pioneer in its own branch of the oxy-acetylene industry and their consolidation marked an important step in the development of the oxy-acetylene process.

Formation of the Corporation also made it possible to consolidate much of the research work that had previously been conducted by the individual companies and Union Carbide and Carbon Research Laboratories, Inc., one of the leading research organizations in the United States, was formed to carry on this important phase of the work. This, too, had a profound influence in furthering the development of oxy-acetylene welding and cutting along sound scientific lines.

## DEVELOPMENT OF THE WELDING TECHNIQUE

It is not difficult to understand why the introduction of the oxy-acetylene flame immediately attracted the attention of metal workers and users of metal products. The temperature of the oxy-acetylene flame, estimated to be about 6,000 deg. F., is so far above the melting point of all commercial metals that it provides a means for localized melting of metal

rapidly and under complete control. Furthermore, the character of the flame is such that it has no injurious effect on the metal melted. The fusing together of two pieces of metal by means of the oxy-acetylene flame to form a continuous unit having uniform and homogeneous structure gives the nearest approach to the ideal joint which would, of course, be no joint at all. The oxy-acetylene welded joint is strong, impervious to gases or liquids even at high pressures, and at least as permanent as the parts joined.

Many things had to be learned before the welded joint reached the high state of perfection that it has now achieved. Because of its wide use, steel was naturally the first metal experimented with in developing the technique of oxy-acetylene welding. It was soon found that in order to obtain thorough fusion to the bottom of the weld, it was necessary to bevel the edges of all except very thin material. This led to the use of added metal in the form of welding rod which is thoroughly fused with metal from the two parts being joined in order to fill up the vee formed by the beveled edges.

Gradually the proper technique was developed and as experience was gained other metals were tried. Difficulty was at first experienced with cast iron due to an imperfect understanding of the metallurgical factors involved. It was also found that the use of flux was necessary to insure sound weld metal. As time went on the list of metals that could be welded was extended until today procedures have been developed for welding practically all commercial metals. As new alloys are produced, their welding properties are studied by experts in research laboratories and in the field and proper procedures are devised. Research has been a most important factor in providing exact knowledge of the chemical and metallurgical aspects of welding and in developing correct procedures, better welding rod and more efficient apparatus.

When oxy-acetylene welding was first introduced, it was immediately recognized as a repair method far more efficient than anything that had previously been available. As operators became more proficient, larger repairs were attempted and the spectacular nature of many of these attracted much attention.

Indeed, this tended for a time to overshadow the fact that

oxy-acetylene welding was equally valuable as a production method. In many quarters, however, this phase of the process received serious study and even before the World War, production of welded articles made from sheet, plate and pipe had progressed to a considerable degree.

The War gave a tremendous impetus to the development of the oxy-acetylene process. Under the stress of war-time necessity the advantages of oxy-acetylene welding and cutting stood out with remarkable clearness. In all branches of the activities, from the production of war materials to the repair of

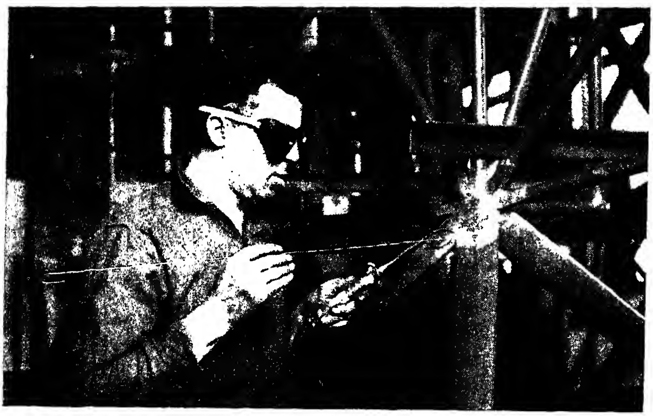


Fig. 3. Oxy-acetylene welding an airplane fuselage—a typical production welding operation.

countless thousands of pieces of equipment at the Front, oxy-acetylene welding served with speed and efficiency.

After the War, the problems of production welding received further engineering study and as a result there was developed the idea of Procedure Control, which effected a transfer of the control of a welding operation from the individual operator to the management, where it properly belongs. Through Procedure Control, welding is now done under complete managerial control, exactly the same as any other production method.

The present scope of oxy-acetylene welding is outlined in more detail in Chapter 2.

## DEVELOPMENT OF OXY-ACETYLENE CUTTING

While the fact that iron or steel when heated red hot will burn in an atmosphere of oxygen has been a familiar chemical laboratory experiment for nearly a century, the idea of applying this reaction to the cutting of iron and steel apparently resulted from a metallurgical practice that developed in Germany almost simultaneously with the early investigations on oxy-acetylene welding blowpipes. This metallurgical practice was the method of tapping blast furnaces by means of a jet of oxygen directed at the previously heated end of an iron plug in the tap hole. Under the action of the jet of oxygen the iron plug was quickly cut allowing the metal to flow from the furnace.

Fig. 4. The oxy-acetylene cutting blowpipe severs steel or iron quickly and economically.

The idea of cutting iron and steel with oxygen apparently developed from this and about 1905 the process was introduced commercially through the development of suitable cutting blowpipes.

Cutting iron and steel with oxygen depends primarily upon the fact that the iron oxide formed has a lower melting point than that of iron or steel. Consequently it melts and forms a fluid slag which readily flows away from the region of the cut, exposing fresh surfaces of iron or steel to the action of the oxygen cutting jet. Theoretically the heat generated in forming iron oxide should be sufficient to maintain the cutting operation after it has been started. In practice, however, it was soon found that a source of heat was necessary not only to heat the metal to the proper temperature for starting the cut, but also to keep the top surface of the metal at a temperature which would permit continuous cutting. The oxy-acetylene flame which

was then being used in an experimental way for welding offered a convenient means for providing such a source of heat. Cutting blowpipes were thus developed with an oxygen jet to do the actual cutting and one or more oxy-acetylene flames to heat the metal to the proper temperature. At the present time cutting blowpipes are equipped with nozzles having a central opening through which the cutting jet passes, and around this several openings for the oxy-acetylene heating flames.

The technique for cutting steel developed rapidly and it was not long before oxy-acetylene cutting became widely used in the metal working industries. The speed of cutting was far in excess of any other available method and the convenience of using the cutting blowpipe was an added advantage.

Recent developments have greatly increased the scope of oxy-acetylene cutting, as outlined in Chapter 2.

CHAPTER 2

# Scope of the Oxy-Acetylene Process

OUTSTANDING characteristics of the oxy-acetylene process are its wide scope and its versatility. No other equipment or process in use by the metal producing or metal working industries is capable of handling such a wide variety of work, so many different metals, or such a range of metal thickness.

The equipment necessary for oxy-acetylene welding and cutting is simple and inexpensive. In its simplest form an oxy-acetylene welding and cutting outfit consists of a cylinder of oxygen, a cylinder of acetylene, two regulators, two lengths of hose, and a welding blowpipe supplemented either by a cutting attachment or by a full-size cutting blowpipe. Mounted on a hand truck such an outfit is readily portable and can be taken to the work no matter where this may be located. With this outfit all commercial metals can be welded; steel, wrought iron and cast iron can be cut within the range of thicknesses that can be handled by a hand cutting blowpipe, and local heating operations can be done effectively.

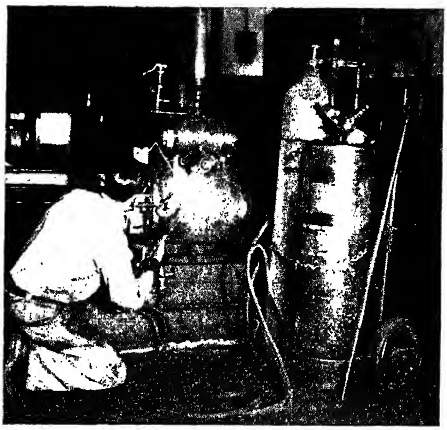


Fig. 5. Oxy-acetylene welding and cutting outfit mounted on a hand truck.

Where larger volumes of work are encountered, generators may be used instead of cylinders as a source of acetylene supply. Acetylene generators are available in a wide variety of sizes for either portable or stationary service.

Similarly the scope of oxy-acetylene cutting may be increased through the use of machines to guide the oxy-acetylene

cutting blowpipe. Cutting machines are available in a wide variety of sizes and capacities.

Applications of the oxy-acetylene process may be considered under three heads: welding; heating; cutting.

## GENERAL PRINCIPLES OF WELDING

As indicated in the discussion in Chapter 1, oxy-acetylene welding is, in principle, simplicity itself. Two pieces of metal are brought together and the edges in contact are melted with the oxy-acetylene flame. The molten metal will flow together until each edge is completely fused with the other. After the metal has cooled, there is a single continuous piece with no seam at all.

Rules for practical application, of course, cannot be stated so easily, but the art of oxy-acetylene welding nevertheless retains this essential simplicity.

*Fusion Welding.* Welds made in the manner just described are known as fusion welds because the base metal is actually melted and fused together with metal from the welding rod. In fusion welding, the base metal and the welding rod generally have essentially the same composition. That is, in fusion welding cast iron, for example, a cast iron welding rod is used.

*Bronze-Welding.* It is also possible to produce sound, strong joints in metals without actually melting the base metal. Thus, in bronze-welding, the edges of the joint are simply heated to a dull red heat by the oxy-acetylene blowpipe flame. With the base metal at the proper temperature and with the aid of a suitable flux, molten bronze from a bronze welding rod will unite with the base metal to form a strong bond. A properly made bronze-weld is quite comparable in strength to a true fusion weld.

In certain other applications of oxy-acetylene welding joints are produced without the thorough fusion of base metal which characterizes fusion welding. Thus, in hard-facing with Haynes Stellite alloy (see Chapter 31) the base metal is brought merely to a sweating heat as it is essential to minimize the intermingling of base metal and hard-facing alloy, which would tend to reduce the efficiency of the latter.

*Welding Flame.* The oxy-acetylene welding blowpipe is a

device for mixing oxygen and acetylene in such proportions as to produce the tremendously hot welding flame when the mixture is lighted at the tip of the blowpipe. Suitable valves give the operator perfect control over the character of the flame at all times.

Many welding operations require a neutral flame. This is produced when the oxy-acetylene mixture in the blowpipe contains essentially equal proportions of oxygen and acetylene. For welding by the Lindeweld process (Chapter 14) and hard-facing with Haynes Stellite alloy (Chapter 31) the blowpipe flame is adjusted so as to contain an excess of acetylene. An oxidizing flame gives best results in fusion welding brass and bronze (Chapter 25) and a slightly oxidizing flame is used in bronze-welding (Chapter 18).

*Preparation of Edges.* In all oxy-acetylene welding, it is essential that the weld should penetrate entirely through the metal. Where the thickness of the metal is such that it would be difficult to secure this penetration if the edges were simply butted together, it is customary to bevel the edges before welding. Placing the two beveled pieces together forms a vee that extends nearly through to the underside of the pieces. The weld can thus be started right at the bottom of the joint.

*Welding Rod.* In order to build the weld up to the original surface, additional metal must be added to fill up the vee. It has been found most practical to use for this purpose metal rods from 1/16 to 3/8 in. in diameter.

*Selection of Material.* Not all metals and alloys respond to the welding flame with equal results. The physical characteristics as well as the chemical composition of the metal affect its behavior under the welding flame. For instance, two lots of steel of about the same chemical composition may show marked differences in weldability. In the fabrication of welded products, it is consequently important to devote some attention to the matter of weldability in selecting the material for the work.

## SCOPE OF OXY-ACETYLENE WELDING

For purposes of discussion, the term welding is used to cover all operations in which parts are joined together or in which metal is added, as in hard-facing.

*Fusion Welding: Neutral Flame.* A neutral flame adjustment is used for the oxy-acetylene fusion welding of practically all commercial metals, such as: cast iron, semi-steel, wrought iron, plain carbon steel, cast steel, alloy steel, stainless steel, copper, aluminum, nickel, Monel metal and lead.

*Fusion Welding: Excess Acetylene Flame.* For high strength welds in plain carbon steels the use of an excess acetylene flame with a special welding rod as in the Lindeweld Process (Chapter 14) increases the speed of welding and improves the efficiency. This process has found wide application in pipe welding, both for overland pipe line construc-

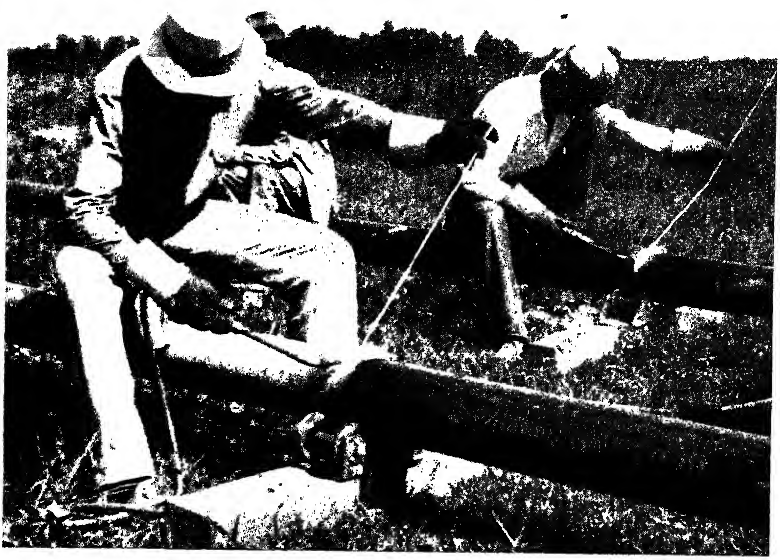


Fig. 6. Thousands of miles of oxwelded pipe lines carry oil, gas and other fluids at high pressures with complete freedom from leakage losses.

tion and for building and industrial piping. The Lindeweld Process has also solved certain of the problems encountered in the fabrication of airplane fittings from chrome-molybdenum tubing.

*Fusion Welding: Excess Oxygen Flame.* The use of an excess oxygen flame adjustment produces weld metal of superior quality in welding many types of brasses and bronzes.

*Bronze-Welding.* Bronze-welding is a method for producing strong joints in metals having melting points higher than that of the bronze welding rod used. In bronze-welding the base metal is not actually fused but a joint of high strength is produced through the formation of a strong bond between the bronze weld metal and the base metal. Bronze-welding is widely used for joining cast iron, semi-steel, malleable iron, wrought iron, galvanized iron, carbon steels, cast steels, copper, nickel, Monel metal. It is also valuable as a means for joining dissimilar metals such as iron to copper or to brass.

*Bronze-Surfacing.* The term bronze-surfacing is applied to the operation of building-up worn metal surfaces with bronze welding rod. The operation is, of course, similar to bronze-welding, but here the object is the building-up of a surface rather than the repair of a fracture or the joining of two parts.

*Hard-Facing.* The life of metal parts subjected to extreme wear or abrasive action can be greatly increased by applying a coating of the hard-facing alloys, such as those known by the brand names, Hascrome, Haynes Stellite and Haystellite. These materials are all available in the form of welding rod and are easily applied by means of the oxy-acetylene welding blowpipe. In the case of Haystellite tungsten carbide, a material infusible even in the oxy-acetylene flame, the welding rod is formed of Haystellite particles embedded in High Test steel welding rod.

*Brazing and Hard Soldering.* Although brazing and hard-soldering are not true welding operations, they are methods for joining metals. The oxy-acetylene welding blowpipe is frequently used in brazing operations where the brazing material is used in the form of spelter. Recently it has been found that the oxy-acetylene welding blowpipe can be very effectively used in hard-soldering the new solder-type fittings for copper pipe that is to be used at high temperatures where the soft solder ordinarily used with these fittings would not be satisfactory.

## SCOPE OF HEATING OPERATIONS

The intense concentrated heat of the oxy-acetylene flame provides a most efficient means for local heating.

*Preheating.* The welding blowpipe flame is frequently used

as a means of preheating small metal parts prior to oxy-acetylene welding.

*Forming.* Metal parts, from the most delicate ornamental iron work to heavy steel plate can be quickly heated at exactly the right spot to permit bending, shaping or otherwise forming the part.

*Annealing.* Under suitable control, the oxy-acetylene flame can be used for the annealing of metal parts after welding particularly where it is desired to control carefully the rate of cooling of the part.

*Special Applications.* The oxy-acetylene flame has also been found most effective in certain other heating applications, as in wood treatment for the production of an antique finish or for charring the surface of wood as an aid in preservation.

*Air-Acetylene Flame.* For many operations which do not require the high temperature of the oxy-acetylene flame, the flame produced by simply burning acetylene in air provides a most useful source of heat. Typical applications (described in detail in Chapter 34) are: soldering, wire splicing, paint burning and babbitting.

## GENERAL PRINCIPLES OF CUTTING

At first thought, it may seem strange that the oxy-acetylene process should embrace two such divergent operations as welding and cutting, one being the exact opposite of the other.

*Fundamental Principle.* The familiar high school experiment of a piece of steel wire burning brilliantly in a test tube of oxygen illustrates the scientific principle that forms the basis of oxy-acetylene cutting. Above a red heat iron combines with pure oxygen so rapidly that it actually *burns.*

Thus if a spot on a piece of iron or steel is heated red hot and a jet of oxygen directed at the hot spot, the iron will begin to burn vigorously. Heat is generated, just as the burning of a piece of wood produces heat. There is a difference, however, for when wood burns the products of combustion are principally two gases known as carbon dioxide and water vapor, while iron and oxygen combine to form iron oxide, a material that is solid at ordinary temperatures. This iron oxide, however, melts at a temperature somewhat below the melting point of iron or steel. The heat generated by the

burning iron is sufficient to melt the iron oxide so that it runs off as molten slag, exposing more iron to the action of the oxygen jet. The jet can thus be moved along, producing a clean cut.

*Cutting Flame.* Theoretically, the heat generated by the burning iron should be sufficient to heat adjacent iron red hot so that once started the cut could be continued indefinitely with oxygen only. Practically, the smoothness of this theoretical operation is disturbed by excessive radiation at the surface, by pieces of dirt, paint or scale on the metal, so that unless additional heat is applied the cut would be stopped. Accordingly the cutting blowpipe has, in addition to a central opening that supplies the oxygen jet, a number of small oxy-acetylene heating flames. From two to six of these flames are arranged symmetrically around the central opening in the cutting nozzle.

To start the cut, these flames are used to preheat a spot to a red heat. Then when the valve controlling the oxygen jet is opened, the cut will start. The preheating flames remain burning while cutting is in progress in order to make up for the radiated heat lost at the surface.

## SCOPE OF OXY-ACETYLENE CUTTING

Oxy-acetylene cutting provides a rapid and economical method for severing steel, wrought iron and cast iron. As oxy-acetylene cutting is a chemical process, increase in thickness of the metal to be cut imposes relatively little difficulty as compared with mechanical processes of severing.

In addition to the normal techniques used in cutting plain carbon steels, special techniques have been developed for cast iron, 18-8 chrome-nickel steel risers, and for oxygen lance work.

A large volume of oxy-acetylene cutting is done free-hand with a hand cutting blowpipe. The operation is quite simple and proficiency is readily acquired by the average workman. The oxygen lance is also manually operated. Used alone, the oxygen lance performs such operations as opening tap holes in blast furnaces, open hearth furnaces and ladles in steel mills, and piercing holes in heavy sections. Two oxygen lances or an oxygen lance and a cutting blowpipe may be used to sever

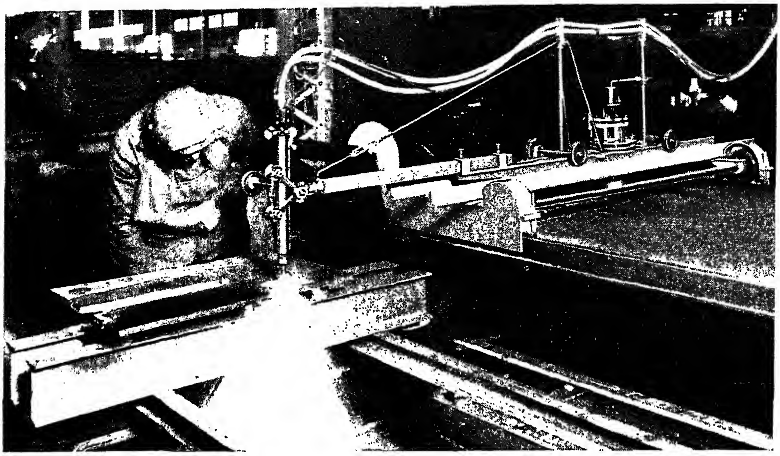


Fig. 7. Automatic oxy-acetylene cutting machines shape steel parts quickly and economically.

steel of almost unlimited thickness. Masses of steel 8 ft. in thickness have been cut by this method.

Where greater precision of cutting is desired, cutting blowpipes are mounted in machines. Cutting machines of various types are available. Perhaps the simplest type is the straight line cutting machine, used for trimming or beveling the edges of steel plate. Special machines have been developed for such operations as cutting and beveling pipe. The acme of machine flame cutting is reached in the shape cutting machine, by means of which regular or irregular shapes of almost any size or thickness may be cut. In these machines, the cutting blowpipe is usually guided automatically by a templet. This permits the production of any number of identical parts.

At the present time oxy-acetylene cutting finds countless applications throughout the entire industrial field. Some of the more important uses are: in steel foundries for the removal of risers from castings; in forge shops for cutting billets; in structural steel work for general use, both in the fabricating shop and during erection; in plate, tank and sheet metal shops; in scrap yards, for the rapid and economical reduction of large pieces to the most convenient size.

CHAPTER 3

# Oxygen and Acetylene

IN order to make the oxy-acetylene process universally available, convenient sources of oxygen and acetylene are essential. Technical details of manufacture and distribution methods have been perfected until supplies of these gases can now be obtained in every part of the country.

## OXYGEN—ITS PRODUCTION

While the operator of welding apparatus is not concerned with the technical details of how oxygen is made, he should have a general idea of the methods used.

The bulk of the enormous volume of oxygen used today is obtained from air by the liquid air process. A relatively small amount is made from water by an electrolytic process.

*Liquid Air Process.* Air is about one-fifth oxygen, the rest being nitrogen with a small percentage of rarer gases such as argon, neon and helium. The gases in the air are simply mixed together and not chemically united in any way. This does not mean, however, that their separation is an easy matter. Special machinery and most expert supervision are necessary for the carefully controlled processes of compression, cooling and expansion required to change air from a gas into a liquid.

The liquid air thus obtained is an intensely cold mixture of liquid oxygen and liquid nitrogen. Oxygen is separated from this liquid mixture by a process known as rectification, in which advantage is taken of the fact that liquid nitrogen boils at a lower temperature than liquid oxygen. The rectifying apparatus delivers high purity oxygen to a storage holder, from which it is compressed into steel cylinders for shipment.

*Electrolytic Process.* Water is a chemical compound of hydrogen and oxygen, both of which are gases at normal temperature and pressure in their free, or uncombined, state. When, under suitable conditions, an electric current is passed

though water, bubbles of oxygen rise from one terminal plate or electrode, and bubbles of hydrogen from the other electrode. This method of effecting a chemical change by means of an electric current is known as an electrolytic process.

For commercial production of oxygen by this method, the equipment consists of a series of units or cells, narrow rectangular metal boxes, inside which are metal plates properly connected to a source of direct current. A solution of caustic soda is put in the cells, and as the cell operates, distilled water is added from time to time in order to replace the water that has been broken up into oxygen and hydrogen. Gas-tight partitions between the positive and negative plates are necessary to prevent the hydrogen and oxygen from mixing in the cells.


**Fig. 8. Oxygen and acetylene cylinders.**
Left—Linde oxygen cylinder, 220 cu. ft. capacity. Right—Prest-O-Lite acetylene cylinder, 300 cu. ft. capacity.

## OXYGEN—ITS COMMERCIAL DISTRIBUTION

It has been found convenient to ship oxygen compressed in steel cylinders. These cylinders are drawn from a single plate of high grade steel, carefully heat-treated so as to develop great strength and toughness. Before use they must be tested with water pressure at 3,360 lb. per sq. in. This same severe test is repeated at 5-year intervals while the cylinder is in use. At the slightest indication of weakening, or sign of damage during use, the cylinder is withdrawn from service. These cylinders are subject to Interstate Commerce Commission rules.

The letters U.S.P. on cylinders of Linde oxygen indicate that this product conforms to the standards established by the United States Pharmacopoeia for certain products used for

medical purposes. All Linde oxygen is of such high purity that, in addition to its industrial uses, it is suitable for human consumption in the treatment of respiratory and other diseases.

*Cylinder Valves.* Each cylinder must have a valve, designed specially to operate at high pressure. The Linde oxygen cylinder valve has a double seat, so it is perfectly tight when fully open or fully closed. The valve should always be opened as far as it will go. A fairly strong grip on the hand-wheel is all that is required to open or close it; a wrench should not be used.

An iron cap that screws on the neck ring of the cylinder protects the valve from damage. Except when the cylinder is in use, this protecting cap should be in place.

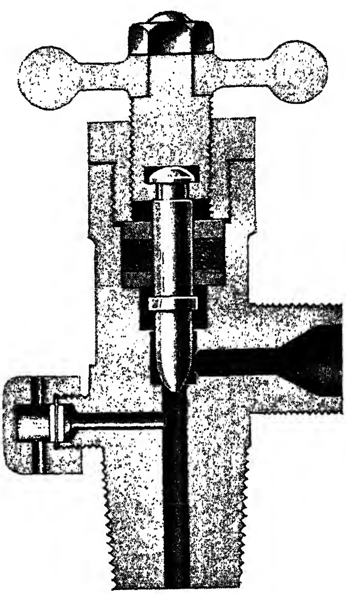


Fig. 9. Cross-section of Linde oxygen cylinder valve.

*Pressure in a Cylinder.* Cylinders are charged with oxygen at a pressure of 2,000 lb. per sq. in. at 70 deg. F. Since all gases expand when heated and contract when cooled, the pressure of oxygen in the closed cylinder will, of course, go up or down as the temperature changes. If, for example, a full cylinder of oxygen is allowed to stand outdoors for several hours when the temperature is, say, 30 deg. F., or just below freezing, the pressure of the oxygen will register approximately 1,800 lb. per sq. in. This does not mean that any oxygen has been lost; cooling the oxygen has merely reduced its pressure. Placing the cylinder in a warm room at 70 deg. F. will again bring the pressure back to 2,000 lb. Here again, no oxygen has been gained; warmth has merely increased the pressure. The accompanying table shows how the pressure of a full cylinder will vary as the temperature changes.

| Temperature of Oxygen Deg. F. | Gauge Reading, Lb. per sq. in. | Temperature of Oxygen Deg. F. | Gauge Reading, Lb. per sq. in |
|---|---|---|---|
| 70 | 2000 | 30 | 1804 |
| 60 | 1951 | 20 | 1755 |
| 50 | 1902 | 10 | 1706 |
| 40 | 1853 | 0 | 1657 |

When the temperature on a warm day goes above 70 deg. F., the pressure in a full cylinder will rise above 2,000 lb. per sq. in. To provide against a dangerous excess of pressure such as might occur if the cylinder were directly exposed to fire, every cylinder valve has a safety device to blow off the oxygen long before there is any danger. For instance, the Linde cylinder valve has a safety nut containing a disk of special metal that will burst if either the temperature or pressure gets too high. Consequently, oxygen cylinders should not be stored or used where they might become overheated; should this happen, the safety disk will break and the oxygen will be lost.

*Size and Weight.* The high charging pressure makes it possible to put 220 cu. ft. of oxygen into a cylinder about 56 in. tall (including the valve) and 9 in. in diameter; and 110 cu. ft. of oxygen into a cylinder about 48 in. high and 7 in. in diameter. These are the two sizes commonly used for welding and cutting. The 220 cu. ft. cylinder weighs approximately 148 lb. full and 130 lb. empty. The average weight of the 110 cu. ft. cylinder is 101 lb. full and 93 lb. empty.

*Safety Precautions.* It is important to remember that pure oxygen under pressure is an active substance. It will cause oily and greasy materials to burst into flame with almost explosive violence. Remember this at all times when using oxygen. Take all precautions to keep oil and grease away from oxygen cylinders, regulators and other welding equipment. Never use oxygen to impose head pressure on a tank. Never confuse oxygen with compressed air. Study carefully the precautions and safe practices given in Sections A and B of Chapter 40, pages 296 to 299.

*Sales Practices.* Oxygen cylinders are not sold but remain the property of the oxygen manufacturer. They are loaned to customers, usually free for a period of 30 days, after which they are subject to a demurrage charge. Oxygen prices are

ordinarily quoted f.o.b. the nearest warehouse or producing plant. The customer pays for delivery of full and return of empty cylinders.

Oxygen cylinders are shipping containers for compressed gas, and are subject to the complex rules and requirements of the Interstate Commerce Commission and other regulatory bodies. This is one reason why the cylinders are not sold. By retaining ownership of the cylinders, the oxygen company assumes all responsibility for complying with the various regulations and thus relieves the customer of much unnecessary bother and expense.

In order to make oxygen readily available in all localities as well as to keep down transportation charges, oxygen manufacturers have established plants in many industrial centers and these are supplemented by distributing stations. Motor trucks are used in supplying customers near plants and distributing stations; those farther away are promptly served by freight or express.

Fig. 10. A safe carrier for hoisting oxygen cylinders.

## STORING AND HANDLING OF OXYGEN CYLINDERS

While oxygen cylinders are very strong and rugged and designed to withstand ordinary handling, they should not be dropped off platforms, knocked about or placed where heavy articles might fall on them. Never use a lifting magnet, rope or chain sling when moving cylinders; use a safe cradle or platform carrier when hoisting them about.

Do not store cylinders in unusually hot places for the reasons given above.

At all times, take particular care to keep oil and greases away from oxygen. Never store oxygen cylinders near oil, grease, or other combustibles. In using the cylinders, do not place them where oil might drop on them from overhead bearings or machines. Oxygen should never be used in pneumatic tools, to start internal combustion engines, to blow out pipe or hose lines, to "dust" clothes, or for creating head pressure in a tank of any kind.

Study also Sections A and B of Chapter 40, pages 296 to 299.

## MANIFOLD AND PIPE LINE DISTRIBUTION OF OXYGEN

Work requiring more than one cylinder of oxygen can be continued without interruption by using a manifold to connect

Fig. 11. Portable five-cylinder oxygen manifold facilitates heavy cutting operations.

together a number of cylinders. For heavy cutting or welding operations, an Oxweld portable five-cylinder manifold is most convenient.

For a continuous supply to a shop or plant, manifolds for six, ten, twenty or thirty cylinders may be used, and the oxygen delivered to the individual stations through pipe lines. Specifications for the installation of oxygen pipe lines can be obtained from the manufacturer, who should always be consulted.

## ACETYLENE AND CALCIUM CARBIDE

All acetylene used commercially is made from calcium carbide, or "carbide", as it is known in the trade. Carbide is a

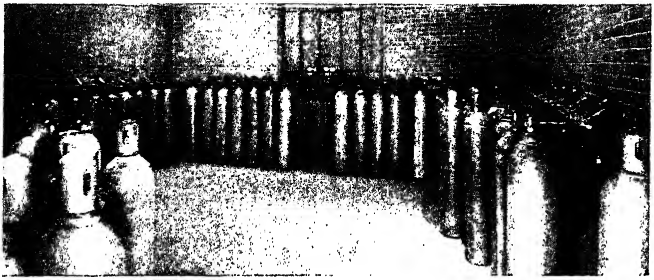


Fig. 12. Wall type oxygen manifold for supplying large volumes of oxygen through piped distribution systems.

gray, stonelike substance, obtained by smelting coke and lime in an electric furnace. The furnace product is crushed, screened to definite sizes and packed in air-tight steel drums.

Carbide factories are usually located near waterpower centers where electricity can be obtained in the required amounts. Warehouse stocks of Union Carbide are maintained in over 250 cities, however, so that it may be obtained in any locality without delay.

*Sizes.* The standard drum contains 100 lb. of carbide. Several sizes of carbide are available for use in acetylene generators. These are designated as follows:

| *Name* | *Limiting Size of Pieces* |
|---|---|
| Lump | 3½x2 in. |
| Egg | 2x½ in. |
| Nut | 1¼x⅜ in. |
| Quarter | ¼x1/12 in. |

The dimensions in the second column indicate the range in the screening sizes of the lumps of carbide. They do not mean for example, that each piece of nut carbide is 1¼x⅜ in. in size, but that no piece is larger than 1¼ in., and none smaller than ⅜ in.

*Carbic Processed Carbide.* Carbic cakes are selected, high grade calcium carbide, specially processed and treated, and compressed into briquet form for use in Carbic generators and flood lights. In the treatment of the carbide before it is compressed, each small piece is thoroughly coated with a material which controls the rate of decomposition when it is in contact with water and also serves as a binder to form the cake. After being compressed, the cakes are treated to protect them from deterioration and to prevent air slaking.

Carbic cakes of the size used to generate acetylene for welding and cutting are 4 in. in diameter and 3 in. high, and weigh about 2½ lb. They are packed in drums containing 40 cakes each; shipping weight 107 lb.

*Acetylene from Carbide.* When carbide is dropped into water, bubbles of gas rise. The gas has a peculiar odor, and if lighted, burns with a smoky flame. This gas is acetylene. After the action has stopped and no more gas is given off, a whitish residue remains in the water. This residue is hydrated (or slaked) lime.

The whole chemical change may be stated in this way: Calcium carbide reacts with water to form acetylene and hydrated lime.

Since acetylene burns and, like any other combustible gas forms explosive mixtures with air, it is clear that acetylene should not be produced for any purpose in make-shift or home-made equipment. Where large amounts of acetylene are required in a welding shop or welding department, it is most economical to make the acetylene on the spot, using for this purpose a suitable generator listed in the inspected appliances of the Underwriters' Laboratories. Users requiring smaller amounts, particularly for portable use, can obtain acetylene in cylinders containing either 100 or 300 cu. ft.

## GENERATED ACETYLENE

Acetylene generators may be classified in two general types, depending on whether the carbide is dropped into the water or the water is allowed to drip on the carbide.

*Water-to-Carbide Generators.* Miners' lamps and similar

small generators are about the only ones in this country using the water-to-carbide principle.

This method is not used in the United States for generating acetylene for welding and cutting. The reasons are not hard to understand. When carbide reacts with water to form acetylene, heat is given off, just as quicklime heats up when slaked. This heat is undesirable, for acetylene when heated tends to change into other compounds. The residue from a water-to-carbide type generator is usually of a yellow color, which is an indication that the temperature has been high enough to affect the acetylene. The yield of acetylene is consequently decreased, and the gas contains impurities.

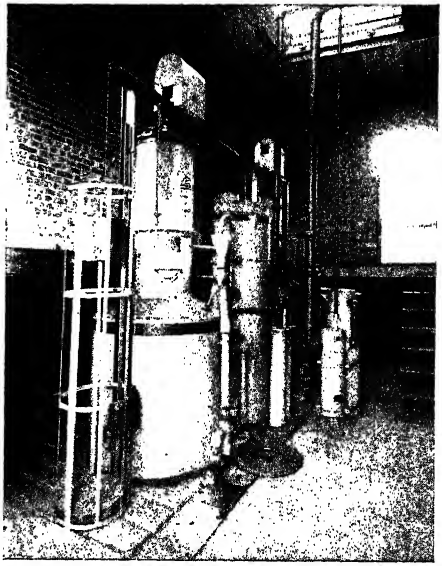


Fig. 13. Oxweld low pressure acetylene generator.

*Carbide-to-Water Generators.* In the carbide-to-water type generator, which is used almost exclusively in this country, small lumps of carbide are fed from a hopper into a comparatively large volume of water. The heat given off during the reaction is readily absorbed by the surrounding water and the acetylene formed bubbles up through the water, being cooled and purified in this way.

While all carbide-to-water generators operate according to the general method outlined above, there is of course considerable variation in mechanical details. Modern acetylene generators for use in welding and cutting are designed to be automatic in operation and as nearly fool-proof as possible. When installing and operating acetylene generators, the manufacturer's instructions should be followed exactly.

*Low Pressure and Medium Pressure Generators.* Generators

are divided into two classes: low pressure, in which the acetylene pressure is less than 1 lb. per sq. in., and medium pressure, which produces acetylene at 1 to 15 lb. per sq. in. Regulations and laws forbid the generation, compression or use of free acetylene at a pressure higher than 15 lb. per sq. in. The reason is that acetylene may explode under certain conditions at pressures above 15 lb. per sq. in. Less than 15 lb. per sq. in. is ample for all welding and cutting operations and is well below the danger line.

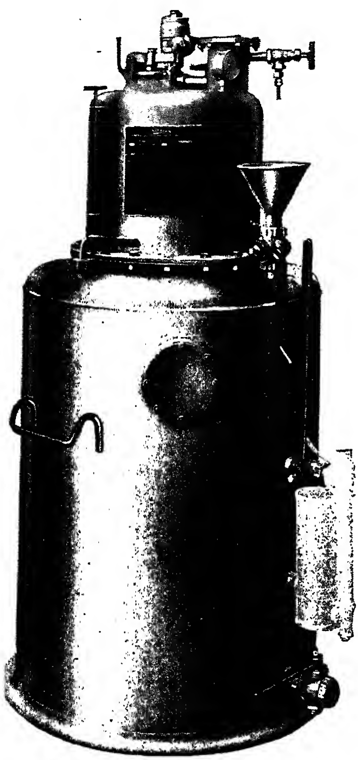


Fig. 14. Oxweld medium pressure acetylene generator.

*Stationary and Portable Generators.* Generators of either low pressure or medium pressure types may be further classified as stationary or portable, according to the type of service for which they are designed.

Both low pressure and medium pressure acetylene generators are available in a wide range of types and sizes for stationary or portable service. Generating capacities range from 45 cu. ft. of acetylene per hr. for a small portable low pressure generator to 6,000 cu. ft. of acetylene per hr. for stationary types for large industrial installations.

*Carbic Generators.* One type of acetylene generator uses carbide in the form of specially prepared Carbic cakes. Carbic generators are uniquely simple in construction. When the gas valve is opened, water rises in the generating chamber until it comes in contact with the lowest Carbic cake, starting generation of acetylene. When the gas valve is closed, the gas pressure forces the water away from contact with the Carbic processed carbide and generation of acetylene stops.

Convenience of charging, ease and economy of operation, and portability make these Carbic generators particularly suitable for a wide range of welding and cutting operations.

*Distribution of Acetylene Gas.* Acetylene is usually supplied from portable generators to the blowpipes directly through standard acetylene hose. One or more blowpipes can be supplied from a single generator, depending upon its capacity. Where a stationary generator is used, the acetylene is distributed by means of pipe lines. Standard practice is to use steel pipe, with all joints welded, but before installing an acetylene line, it is well to consult the generator manufacturer.

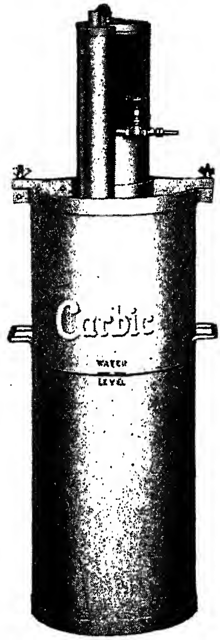


Fig. 15. Carbic generator.

## DISSOLVED ACETYLENE

*Acetylene Cylinders.* Acetylene is widely distributed in cylinders. These are quite different in construction from oxygen cylinders, for, as already noted, free acetylene should not be stored above 15 lb. per sq. in. After much study, the problem of combining safety with capacity was solved by packing the cylinders with a porous material, the fine pores being then filled with acetone, a liquid chemical having the property of dissolving or absorbing many times its own volume of acetylene. In such cylinders, acetylene is perfectly safe. The acetylene dissolved in acetone will not change its nature. The acetylene is made in large stationary generators, purified very carefully and then dissolved into the cylinders.

The cylinder itself is a strong steel container packed completely full of a porous substance which in turn is saturated with acetone. Acetylene is drawn off through a valve, which, in Prest-O-Lite cylinders, is located in a recessed top, where it is protected from breakage. The valve is much simpler than an oxygen valve, not having to withstand as high pressure. It should be opened only 1½ turns. Safety fuse plugs

are provided to meet any fire emergencies and the entire construction must satisfy the requirements of the Interstate Commerce Commission.

*Sizes.* Dissolved acetylene is sold in cylinders having rated capacities of either 100 or 300 cu. ft. The actual acetylene content of these cylinders averages somewhat below the rated capacity, but the customer is billed only for the actual acetylene content of the particular cylinder shipped. Average shipping weights are: for the 100 cu. ft. cylinder, 91.5 lb. full, 85 lb. empty; for the 300 cu. ft. cylinder, 232.5 lb. full, 214 lb. empty. A pressure gauge placed on a full cylinder containing dissolved acetylene would register approximately 225 lb. per sq. in.

*Recharging.* Cylinders should never be charged or recharged except by the manufacturer, who can conduct this operation under careful control.

Numerous plants coupled with many distributing stations make it possible to obtain dissolved acetylene anywhere without difficulty.

## GENERAL SAFETY RULES

*Acetylene Generators.* From the discussion above, it should be perfectly evident that there are already on the market reliable acetylene generators of such variety in type and size as to meet any operating requirements. If an acetylene generator is wanted, buy from a reliable manufacturer one that is listed in the Underwriters' Laboratories list of inspected appliances. Under no conditions should an attempt be made to generate acetylene in make-shift or home-made equipment.

Having purchased an acetylene generator, install it and operate it strictly in accordance with the printed instructions furnished by the manufacturer.

Remember that acetylene forms explosive mixtures with air. Keep flames away from the generator. It is a good plan to do all charging, cleaning and adjusting by daylight. Electric light bulbs should be provided with approved gas-tight globes and fixtures.

Protect the generator from freezing. If water or moisture in any part of the generator should freeze, thaw it with hot

water only. Then examine the generator carefully for any damage which freezing may have caused.

*Acetylene Cylinders.* Remember that acetylene will burn and, like any other combustible gas, will form explosive mixtures with air.

Accordingly, store acetylene cylinders in a well-protected, ventilated and dry place, away from highly combustible materials and from stoves, radiators or furnaces.

Handle the cylinders carefully and always keep them valve-end up, in storage as well as in use.

Never tamper with fuse plugs.

Study also the precautions and safe practices given in Sections A and C of Chapter 40, pages 296 and 299.

## SUPPLEMENTARY READING

Interested persons will find further information in "Calcium Carbide and Acetylene," by G. G. Pond, available through International Acetylene Association, 30 East 42nd Street, New York, N. Y.

CHAPTER 4

# Blowpipes—Construction and Operation

GENERAL *Principles.* Blowpipes perform the essential function of producing an oxy-acetylene flame under conditions of complete control as to size, characteristics and ease of application. While blowpipes vary rather widely in design all types have certain fundamental and common characteristics.

Welding blowpipes have a handle with two inlet connections for gases at one end. Each has a valve that controls the volume of oxygen or of acetylene passing through. By means of these valves, the desired proportions of oxygen and acetylene are allowed to flow through the blowpipe, where they are thoroughly mixed before issuing from the blowpipe at the tip or nozzle. The oxy-acetylene flame is produced by igniting the mixture at the blowpipe tip.

Cutting blowpipes are so designed that the flame is divided into several small jets surrounding a central opening in the tip or nozzle. The central opening, connected to the oxygen inlet through an independent tube and valve, supplies the jet of oxygen that actually does the cutting.

## TYPES CLASSIFIED BY ACETYLENE PRESSURE

Considered from the points of view of construction and operating principles, all oxy-acetylene blowpipes are of two general types, low pressure and medium pressure. The distinction refers to the acetylene pressure range required for operation. As discussed in connection with acetylene generators, page 32, acetylene at pressures less than 1 lb. per sq. in. is designated as low pressure; from 1 to 15 lb. per sq. in., medium pressure.

Low pressure blowpipes can use acetylene from low pressure

generators, medium pressure generators or cylinders. For pressure blowpipes, the acetylene pressure must be more than 1 lb. per sq. in. They can be used with Prest-O-Lite cylinders or medium pressure generators but not with low pressure generators.

Low pressure blowpipes make use of what is known as the injector principle. Oxygen passes through a small opening in the injector nozzle, producing a suction effect which draws acetylene into the oxygen stream. One advantage of this type

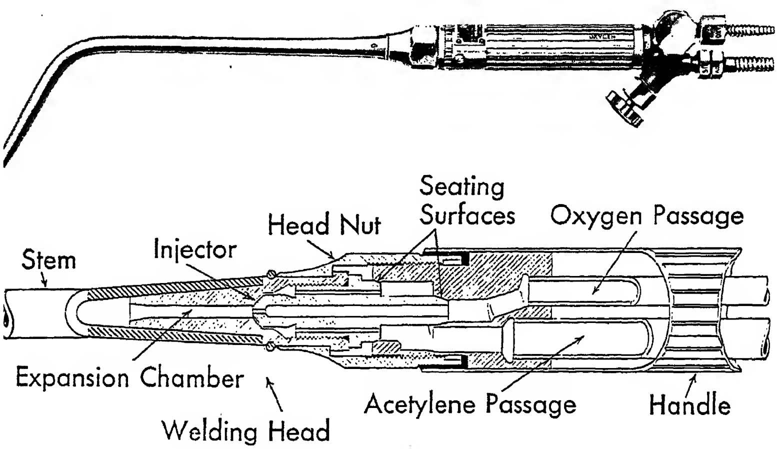



Fig. 16. Typical low pressure welding blowpipe (Oxweld) and schematic cross-section.

of construction is that small changes in the amount of the oxygen will produce a corresponding change in the amount of acetylene drawn into the gas mixture, so the proportions of the two remain substantially constant while the blowpipe is in operation.

In medium pressure type blowpipes, oxygen and acetylene are fed at independent pressures to a mixing chamber, the construction of which varies considerably according to the ideas of different manufacturers.

Medium pressure blowpipes which operate with equal pressures of oxygen and acetylene are also designated as the balanced pressure type.

## CONSTRUCTION OF WELDING BLOWPIPES

*Low Pressure Type.* Fig. 16 shows a typical low pressure welding blowpipe, the Type W-17 Oxweld blowpipe. At the right is the rear body which contains two hose connections and the inlet valves, one for oxygen, the other for acetylene. Attached to this is the handle of the blowpipe which is a brass tube with the front body set in the other end to form the terminal for the two smaller tubes inside the handle and to receive the injector located in the rear of the head.

Mixing takes place in the blowpipe head, the rear end of which is shown in cross-section attached to the handle in Fig. 16. By following the path of the oxygen through the head, it will be seen that it passes through the center of the injector nozzle. Surrounding this nozzle are a number of acetylene passageways. As oxygen passes through the small orifice of the injector nozzle, its velocity is increased and a suction is produced that draws acetylene in through the side

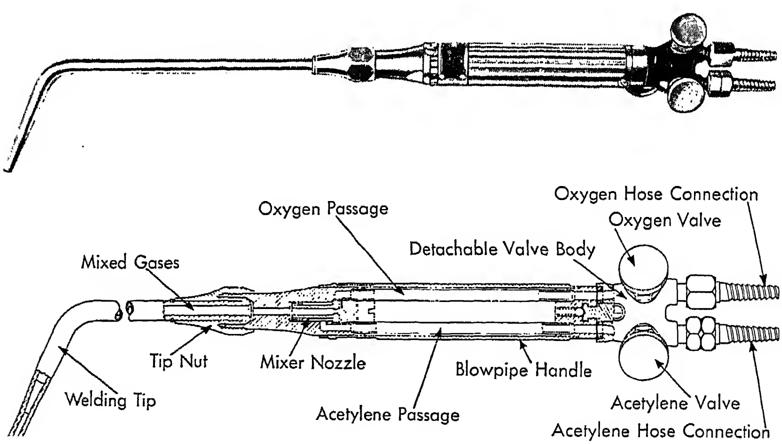



**Fig. 17. Typical medium pressure welding blowpipe (Prest-O-Weld) and schematic cross-section.**

openings. It will be noted that the passage through which the mixed gases then pass increases in diameter as the stem portion of the head is reached. The expansion thus provided

insures thorough mixing of oxygen and acetylene, so the mixture issuing from the blowpipe tip will burn properly.

*Medium Pressure Type.* General design and internal construction of a typical medium pressure welding blowpipe, the Type W-105 Prest-O-Weld blowpipe, are shown in Fig. 17. Similar details are given in Fig. 18 for a typical balanced pressure welding torch, the Purox No. 35 blowpipe.

In medium pressure blowpipes, the oxygen and acetylene are thoroughly mixed by passing through a mixer, located

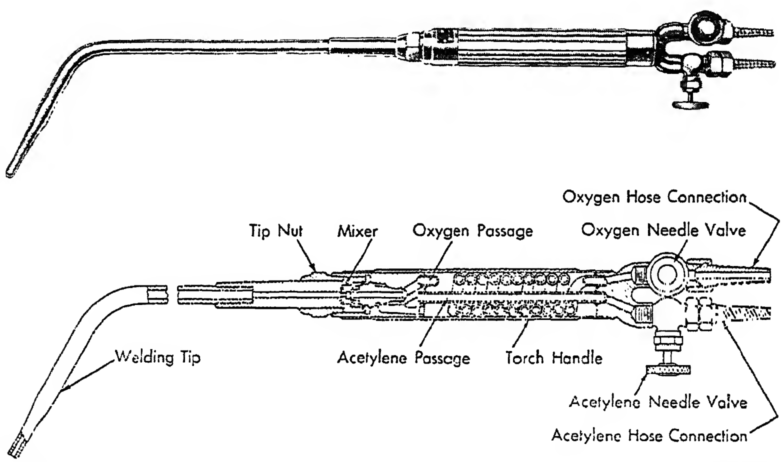



Fig. 18. Typical balanced pressure welding torch (Purox) and schematic cross-section.

either in the front end of the handle or in the rear of the welding head. The mixture passes forward through the tip where it is ignited to form the oxy-acetylene flame.

*Interchangeable Heads or Tips.* Practically all welding blowpipes are provided with a series of interchangeable heads or tips of different sizes so that the same handle can be used on a wide variety of operations.

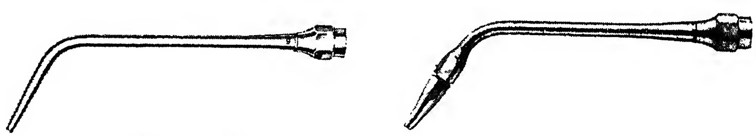
For some types of welding blowpipes, the heads are available either with a one-piece drawn stem or with a stem provided with a detachable tip. The head with detachable tip is preferable when it is to be subjected to considerable abuse during welding.

The tips, which in operation are nearest to the work and must, consequently, resist heat, are made of special drawn copper. The blowpipe may be changed very quickly from one job to another simply by changing the welding head or tip.

A cutting attachment can be put on in place of a welding head for light or occasional cutting jobs.

For certain blowpipes there are also available extra long welding heads or tips of large capacity for heavy duty service or for heating operations where an unusually large amount of heat is required.

The Prest-O-Weld blowpipe has, in addition to interchangeable tips, a unique feature which further increases the ease of interchange. This is a detachable valve body, by means of which a single valve body may be used with a large welding blowpipe, a small welding blowpipe, a large cutting blowpipe or a cutting attachment. By the mere turn of a simple locking



One-piece type. Detachable tip type.

Fig. 19. Typical interchangeable heads for welding blowpipe.

device, it can be changed instantly from one blowpipe handle to another, without the use of a wrench and without disturbing the hose or hose connections.

*Blowpipes for Specialized Service.* In addition to a general duty blowpipe for average work, each manufacturer has a number of other types for more specialized service. These include blowpipes for aircraft, sheet metal and automotive, pipe line, lead burning and machine welding operations.

## CONSTRUCTION OF CUTTING BLOWPIPES

In the cutting blowpipe, the oxy-acetylene flame is produced at a series of openings in the blowpipe tip or nozzle which surround a larger central orifice. This central passageway is connected with the oxygen inlet and has a separate controlling valve, operated by a conveniently located cutting valve lever on the blowpipe handle. As was explained on page 21, the

function of these oxy-acetylene flames is merely to preheat the metal that is to be cut. The use of a number of preheating flames, rather than a single one, makes it possible to change the direction of the cut as desired.

*Low Pressure Type.* The construction of a typical low pressure cutting blowpipe, the Type C-24 Oxweld blowpipe,

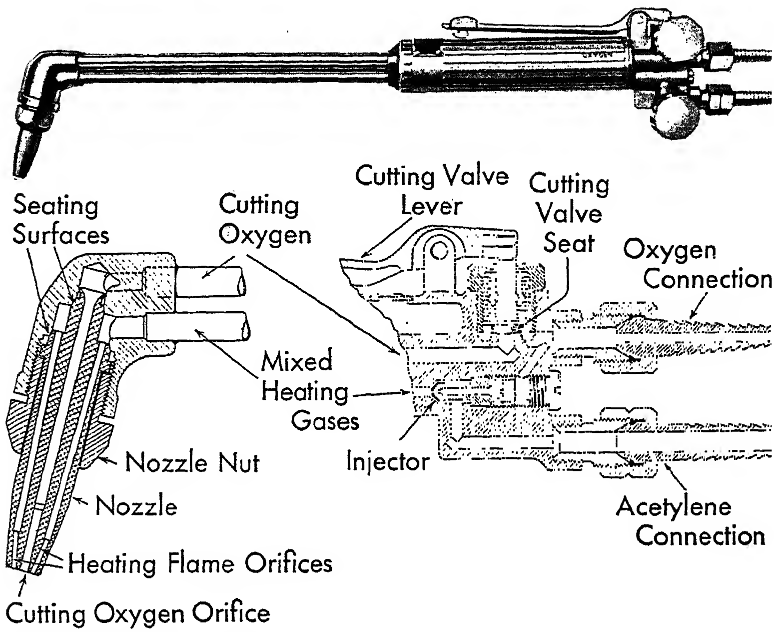



Fig. 20. Typical low pressure cutting blowpipe (Oxweld) and schematic cross-section.

is shown in Fig. 20. The oxygen and acetylene for the heating flames are mixed by means of the injector, which functions in exactly the same manner as in the low pressure welding blowpipe.

*Medium Pressure Type.* A typical medium pressure cutting blowpipe, the Type C-105 Prest-O-Weld blowpipe, is shown in Fig. 21; a typical balanced pressure cutting torch, the Type E Purox blowpipe, in Fig. 22.

*Interchangeable Nozzles.* Simply by changing the size of the cutting nozzle or cutting tip, a single cutting blowpipe can be used to cut a wide range of metal thickness. Interchange-

able nozzles used on cutting blowpipes may be of one-piece or two-piece construction. In one-piece construction the necessary holes for preheating flames and cutting jet are drilled through a solid piece of metal, usually pure drawn copper. The two-piece nozzle has an external nozzle of pure copper that is used with any one of the series of brass internal nozzles.

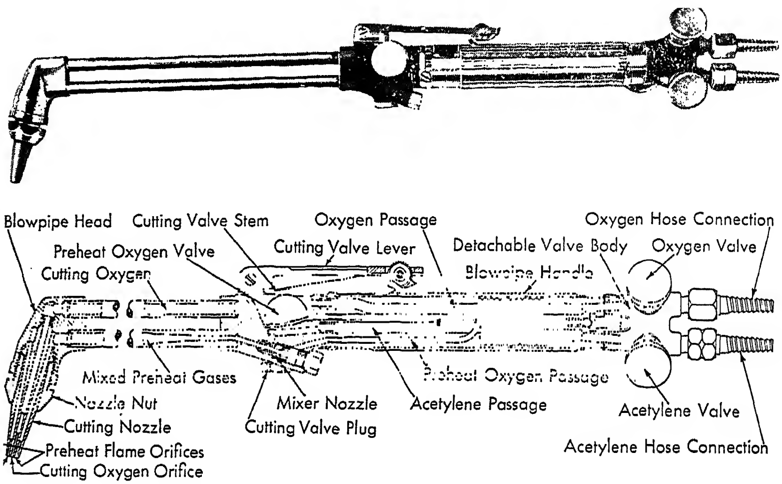



Fig. 21. Typical medium pressure cutting blowpipe (Prest-O-Weld) and schematic cross-section.

For certain types of cutting blowpipes, there are also available special cutting tips or nozzles for such operations as rivet cutting, cast iron cutting and sheet metal cutting.

*Blowpipes for Specialized Service.* In addition to a general duty cutting blowpipe, each manufacturer has a number of other types for more specialized service. These include cutting attachments for use with welding blowpipes, heavy duty blowpipes, and machine cutting blowpipes for use on oxy-acetylene cutting machines, which are discussed in Chapter 39.

## CARE OF BLOWPIPES

The warning "Oxygen—Use No Oil" printed on regulators applies also to blowpipes for they contain oxygen under pressure.

Before using a new blowpipe for the first time, tighten the

packing nuts on the blowpipe oxygen and acetylene valves. It is customary to ship blowpipes with these packing nuts loose.

If the orifices in the blowpipe tips or nozzles become clogged, clean them with the proper size drill or with a soft

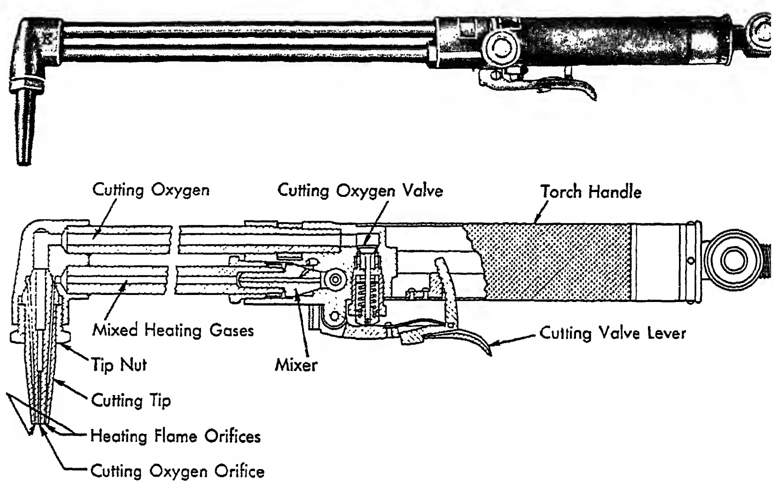



Fig. 22. Typical balanced pressure cutting torch (Purox) and schemati cross-section.

copper or brass wire. A sharp, hard tool which would enlarg or bellmouth the orifices, must not be used. Clean the orifice from the *inner* end wherever possible.

Study Recommendations K-1 to K-7 in Chapter 40.

CHAPTER 5

# Regulators—Construction and Operation

THE pressures at which oxygen and acetylene enter the blowpipe are much below the pressures in the cylinders. Accordingly some means must be provided for reducing the relatively high cylinder pressure to the lower working pressure. Furthermore, in order that the blowpipe flame may be perfectly steady and uniform, the pressure of the gases reaching the blowpipe must not fluctuate. Regulators perform both of these important functions. They can be set to reduce the cylinder pressure to any desired point and maintain this pressure constant without further attention.

*Function.* In order to understand more clearly just what this means, let us take a specific example. Let us assume that we have a cylinder containing oxygen at 2,000 lb. per sq. in. and that we wish to do some welding that requires only 10 lb. oxygen pressure at the blowpipe. We must have a regulator that can be set so as to deliver oxygen at 10 lb. pressure. That is, the regulator must function as a reducing valve, reducing 2,000 lb. pressure to 10 lb. But it must be more than a simple reducing valve, for the cylinder pressure does not remain constant while the blowpipe is in operation. After welding several hours with that one cylinder, for example, half of the oxygen may be used, and the pressure in the cylinder will then be 1,000 lb. instead of the original 2,000 lb. But we still need 10 lb. at the blowpipe.

Consequently, in order to maintain working pressure constant regardless of what the cylinder pressure may be, regulators must have a sensitive regulating mechanism in addition to a reducing valve. It is evident that such a device, to be of any use at all, must be of a sensitive nature, and yet the regulator itself must be rugged enough to stand necessary shop handling. To design such a piece of equipment that will

operate accurately day in and day out under all sorts of working conditions is a real engineering problem.

Through long experience, Oxweld engineers have developed types of regulators that will meet all the varied requirements of oxy-acetylene welding and cutting. Figs 23 and 24 are external views of typical regulators.

*General Design.* A regulator has a union nipple for attaching to the cylinder and an outlet connection for the hose leading to the blowpipe. There are two gauges on the body of the regulator, one showing pressure in the cylinder, the other the working pressure being supplied to the blowpipe. The working pressure is adjusted by means of a handscrew. When this

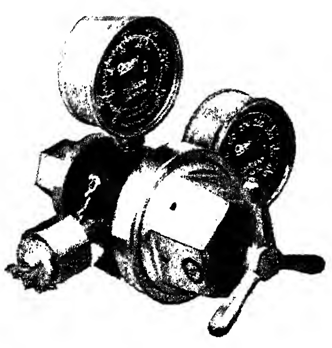


Fig. 23. Oxygen regulator.

Fig. 24. Acetylene regulator.

pressure adjusting screw is turned to the left (counter-clockwise) until it runs free, the valve mechanism inside the regulator is closed. No gas can then pass to the blowpipe. As the handle is turned to the right (clockwise), the screw presses against the regulating mechanism, the valve opens and gas passes to the blowpipe at the pressure shown on the working pressure gauge. Changes in this pressure are made at will simply by turning the handle until the desired pressure is registered.

Before opening the valve on a cylinder to which a regulator is attached, it is most important to make absolutely certain

that the pressure adjusting screw is fully released by turning to the left. As noted above, this closes the valve inside the regulator. The cylinder valve can then be opened.

## REGULATING MECHANISM

Although the mechanical details of regulator construction vary among different manufacturers, the fundamental oper-

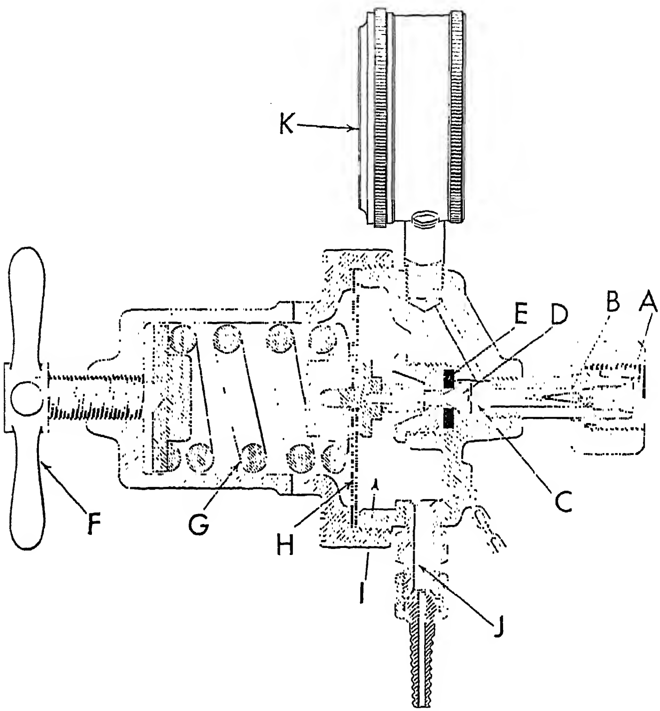



Fig. 25. Cross-section of stem type regulator.

ating principles are the same for all welding and cutting regulators. These principles may be explained by a consideration of the typical regulator shown in Fig. 25. This is an oxygen regulator with stem type regulating mechanism; the same principles apply to acetylene regulators and, basically, to other types of mechanism.

*High Pressure Chamber.* With the pressure adjusting screw *F* turned to the left (counter-clockwise) until fully released, the valve *D* is held closed by the small spring around the valve stem.

When the cylinder valve is opened, oxygen from the cylinder enters the regulator through inlet connection *A*, passing through the inlet screen *B* to the high pressure chamber *C*. The purpose of the screen is to keep out particles of dirt or other matter that might lodge on or damage the regulator valve seat. Because valve *D* is closed, the oxygen is confined to the high pressure chamber *C* where it rapidly builds up pressure to the cylinder pressure, as indicated on the cylinder pressure gauge *K*, which is connected with chamber *C*. It will be observed that valve *D* closes *with* the pressure—the greater the pressure the tighter valve *D* is forced against valve seat *E*.

*Pressure Reduction.* When the pressure adjusting screw *F* is turned to the right (clockwise) compressing pressure adjusting spring *G*, the motion is transmitted to the diaphragm *H* and to the valve stem *D*. When the force exerted by spring *G* overcomes the opposing action of the valve spring and of the high pressure oxygen on the head of valve *D*, the valve *D* will open. Oxygen will then flow from the high pressure chamber through the annular opening around the valve stem into the working pressure chamber *I*, thence through the outlet *J* and hose connection to the blowpipe. If the blowpipe oxygen valve is open, the flow will continue at the pressure indicated on the working pressure gauge which is connected with the working pressure chamber. Obviously, the more pressure applied by the spring *G* against the diaphragm *H*, the higher will be the pressure in the working pressure chamber. Thus any working pressure within the capacity of the regulator can be obtained at will by simply turning the pressure adjusting screw until the desired pressure is indicated on the working pressure gauge. The corresponding blowpipe valve should always be open when adjusting the working pressure.

*Pressure Regulation.* Assume next that the blowpipe oxygen valve is now closed. Pressure immediately builds up in the working pressure chamber *I* and reacts on the diaphragm *H*. This diaphragm is a flexible disk of specially reinforced vulcanized rubber and consequently can move in or out with

changes in pressure in the working pressure chamber. As the pressure on diaphragm *H* increases, spring *G* is compressed and valve *D* closes, shutting off the flow of high pressure oxygen.

Spring *G* is now held in compression by the pressure of oxygen in the working pressure chamber *I* against the diaphragm *H*. As soon as the pressure on the diaphragm is reduced slightly by opening the blowpipe oxygen valve, spring *G* expands and reopens valve *D*.

This reciprocal or balanced action, involving the diaphragm, the pressure adjusting spring and the valve spring, constitutes

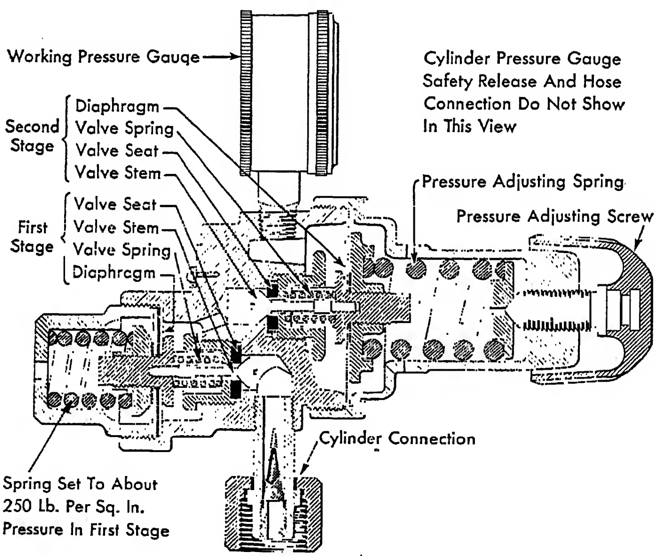



**Fig. 26. Cross-section of two-stage regulator.**

the regulating mechanism. For the sake of simplicity, the explanation above covered merely the action of the mechanism in stopping and starting the flow of oxygen to the blowpipe. Actually the mechanism also functions constantly while the regulator is in operation, that is, while valve *D* is open. Thus, as oxygen is drawn from the cylinder, the pressure in the cylinder falls gradually. The sensitive diaphragm reacts con-

stantly to this gradual drop in pressure and allows spring *G* to open valve *D* farther to compensate for this so as to maintain the working pressure constant.

## TWO-STAGE REGULATORS

In the recently developed two-stage oxygen regulators, the pressure reduction is accomplished in two separate steps. This type of regulator has two independent diaphragms and stem type valve assemblies, which make operation extremely efficient. (See Fig. 26.) The full cylinder pressure of 2,000 lb. per sq. in. enters the regulator and is reduced to about 250 lb. by the first stage extra heavy diaphragm with its complement of heavy springs. This first stage is entirely automatic and non-adjustable. The second stage is similar in design to the first stage but has a larger diameter diaphragm and lighter springs. It is adjustable by the operator to any desired working pressure by turning an adjusting screw. Instead of having to carry the full cylinder pressure load of 2,000 lb. per sq. in., the second stage is required to function within only a comparatively narrow range. This dual arrangement of valves and diaphragms insures much more constant delivery pressure adjustment than is possible with single stage type regulators.

## REGULATOR TYPES FOR VARIOUS USES

In practice, regulators are classified according to the use for which they are designed. The two major groups are of course regulators for oxygen and regulators for acetylene. Each of these groups is again subdivided as will be shown in the following sections.

## OXYGEN REGULATORS

Oxygen regulators must be so designed that the high pressure side of the regulating mechanism will take care of the full cylinder pressure, 2,000 lb. per sq. in. It is customary to provide a 3,000 lb. cylinder pressure gauge on oxygen regulators so there is an ample margin to prevent straining the gauge mechanism. The cylinder pressure gauge usually has a second scale which shows the contents of the cylinder in cubic feet at 70 deg. F.

The working pressure side of the regulator varies with the use for which the regulator is intended, as follows:

For welding, the regulator is designed to deliver a maximum of about 50 lb. and usually has a 100 lb. working pressure gauge.

For cutting, which requires higher pressures than for welding, the working pressure gauges are usually 400 lb. The maximum delivery capacity of the regulator may vary from 125 to 200 lb. per sq. in., according to type.

*Manifold Regulators.* Oxygen manifold systems impose severe operating conditions and special regulators are provided. These are capable of delivering large volumes at pressures up to 200 lb. per sq. in. They have 400 lb. working pressure gauges.

For oxygen lance and heavy duty work, there are also available regulators having sufficient capacity for working pressures up to 500 lb. per sq. in. They are provided with 1,000 lb. working pressure gauges.

## SPECIAL POINTS

The warning "Use No Oil" applies to oxygen regulators as it does to all equipment where oxygen under pressure is handled.

To provide against emergencies in which abnormal pressure might build up in the regulator, a rupturing-disk safety release is provided. While failure of the Bourdon tube inside a gauge is a rare occurrence, provision must be made for the pressure that would result if this did happen. On high pressure gauges, the back of the gauge is made so it will open if there should be pressure inside the case. Low pressure gauges have a vent hole in the case.

Study also Recommendations K-8 to K-10 in Chapter 40.

## ACETYLENE REGULATORS

Acetylene regulators for welding and cutting with dissolved acetylene have cylinder pressure gauges registering up to 350 lb. per sq. in. and usually 30 lb. working pressure gauges (graduated only to 15 lb., because acetylene should never be used at pressures above 15 lb. per sq. in.).

Acetylene gauges all have vent holes in the side of the case to relieve any abnormal pressure.

## HYDRAULIC BACK PRESSURE VALVE

A special device is used at each station supplied with acetylene piped from a low pressure generator. In this device, known as a hydraulic back pressure valve, a water seal prevents any reverse flow of gas into the acetylene line or generator.

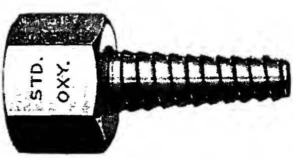
## CHAPTER 6

# Welding and Cutting Accessories

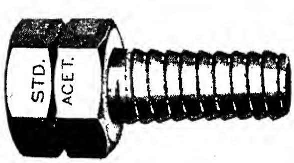
### HOSE

HOSE made specially for welding and cutting should always be used. Two lengths of hose, one for oxygen and one for acetylene, are required to connect the regulators and the blowpipe. Hose for oxygen and hose for acetylene should not be interchanged. The word "Oxygen" is molded into the surface of the oxygen hose at regular intervals and acetylene hose is marked "Acetylene" in a corresponding manner. Green is the standard color for oxygen hose and red for acetylene, the same as the colors of the respective regulators.

*Size.* To serve their purpose best, hose lines should be of a diameter that will permit gases to flow through freely with practically no loss of pressure. This is also true of any connections, valves and piping between the source of gas supply and the blowpipe. In general, use hose of a diameter that will fit the hose connection furnished with the blowpipe. Standard




For oxygen.




For acetylene.

Fig. 27. Standard hose connections.

sizes of hose for oxy-acetylene welding and cutting are designated as $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in.

*Hose Connections.* For connecting hose to blowpipes and regulators, only standard hose connections of the correct size should be used. A hose connection consists of a nipple which is inserted in the end of the hose, and a nut for attaching the nipple to the blowpipe or regulator. To prevent interchange

of oxygen and acetylene hose the standardized oxygen thread is right-hand and the acetylene thread is left-hand. The hose connection nuts are marked "STD. OXY." for oxygen and "STD. ACET." for acetylene. In addition, the acetylene nuts have a groove cut around their center to indicate a left-hand thread, which makes identification easy.

*Clamps and Ferrules.* A hose connection of correct size and type should be inserted in each end of each length of hose.

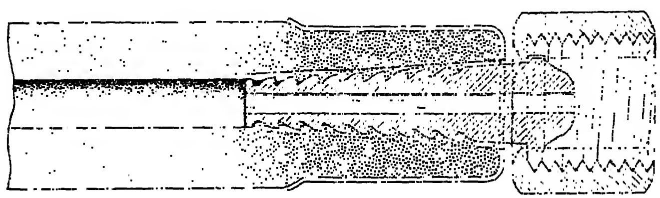


Fig. 28. Cross-section of ferrule type hose connection.

The end of the hose should be squeezed tightly against the nipple by means of a standard hose clamp or ferrule. A ferrule type oxygen hose connection is shown in section in Fig. 28.

In the case of certain light-duty welding blowpipes, the hose nipple is a part of the blowpipe and a hose clamp is all that is needed for attaching the hose.

Study the Recommendations in Section D and K-12 to K-15 in Chapter 40.

## GOGGLES

At all times while welding or cutting or observing such work, the eyes should be protected by goggles designed for use with the oxy-acetylene process. The light from the inner cone of the oxy-acetylene flame is itself quite intense, but the hot metal in the section being welded produces a far greater glare. Eye-strain is sure to result if welding or cutting is done for any length of time without goggles. In welding, the eyes may be very close to the work

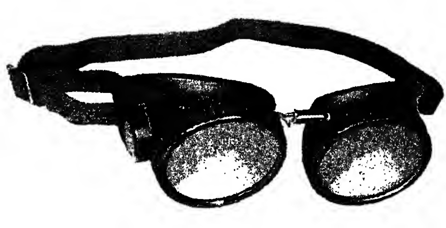


Fig. 29. Welding goggles.

for hours at a time so that the strain is much greater than in most other operations where molten metal is involved.

Aside from the question of glare, the eyes are so close to the work that it is most advisable to be protected against flying sparks or bits of molten metal that may be spattered about. Goggles also protect the eyes from reflected heat which dries the surface of the eye, causing irritation.

Correct goggle lenses are made of special colored optical glass that minimizes the effect of glare and at the same time permits the operator to see his work clearly. Lenses are available in light, medium or dark shades. For the frames, a tough, heat-resisting material is used. Goggles should, of course, be light, comfortable and well ventilated.

Spectacles having correct lenses are also available but they are not generally recommended, except where there will be no bright light or sparks coming from the side, as in small bench work.

## GLOVES

The heat radiated from a welding job of any size makes it advisable to have some protection for the hands. Gauntlet type gloves or mittens of asbestos or other non-burnable material should be worn by the operator.

Gloves should be kept free from oil and grease, for such materials should never come in contact with oxy-acetylene equipment. If much greasy work is to be done, use gloves for handling, but change to a clean pair before touching the welding equipment.

## LIGHTERS

For lighting blowpipes, friction lighters are provided as part of the outfit. These are much better than matches. With a match the hand has to be held so close that it may be burned when the gases ignite. Carrying a box of matches in an overall pocket while welding may result in a severe burn should a spark happen to land in just the right spot. The friction lighter, on the other hand, is perfectly safe under any conditions. The friction metal in the lighter tip is easily renewed.

## WRENCHES

Open-end wrenches of correct size are usually supplied with blowpipes and regulators for use in making the various tight connections required for proper operation of the apparatus.

## WELDING RODS

Welding rods are drawn or cast metal rods of various diameters for various classes of work. During welding, the rods are melted into the joint. Metal from such rods forms a large proportion of the actual weld metal and consequently the rod plays a most important part in determining the quality of the finished weld.

Good welding rods must be of correct chemical composition, and equally important, free from foreign matter or "dirt." The metal from the rod changes somewhat in its chemical composition and its properties after passing through the welding flame. A good welding rod, naturally, has its composition so fixed as to provide for these changes, so the metal in the weld will be of as good quality as, or better than, parts being joined. Good rods will melt and flow freely and will unite readily with the base metal, producing sound, clean welds.

Fig. 30. Welding rod quality is constantly checked by flame test.

*Test for Quality.* The behavior of a welding rod in the blowpipe flame gives a good indication of its quality. It must melt quietly and without excessive sparking.

It is advisable to buy rods only from a reputable manufacturer. The difference in price between the best rods obtainable and inferior rods is too small a portion of the total cost of a job to warrant the risk of failure when using the low grade rods.

Welding rods are made in various diameters from $1/16$ in. to

$\frac{3}{8}$ in. As a rule, the diameter of the welding rod should correspond with the thickness of the material being welded.

Welding rods should be stored in such a way that the different kinds of rod will not get mixed up. Steel and cast iron rods should be kept dry so they will not rust. Some manufacturers apply a very thin coating of copper or of grease to prevent rust. These coatings should not be confused with "dirt" referred to above. Dirt in the metal or on it are alike harmful.

The general properties and characteristics of different kinds of welding rods are discussed in the chapters on the various metals. In fusion welding, the welding rod is generally similar to the base metal. In bronze-welding, however, the same kind of rod is used for a wide variety of base metals.

## FLUX

At welding temperatures all metals oxidize (that is, form chemical compounds with oxygen from the air) more or less rapidly and the oxides so formed act as so much "dirt." If permitted to remain in the finished weld, the oxide would seriously reduce the strength of the weld and might even make it quite useless.

It so happens that in welding steel, oxides of the various elements form and unite together into a slag that fuses at a lower temperature than that required to melt the steel. This slag tends to float to the surface of the weld. With care on the part of the operator, these oxides can be collected on the top of the puddle of molten metal and thus removed from the joint. This action is expedited by the use of special High Test welding rods, which contain alloying elements acting as self-cleansers.

*Use Proper Flux.* With cast iron and aluminum (in fact, with practically all of the common metals except steel) the temperature of the molten metal is considerably below the melting point of the oxides which form, so that the latter remain in the weld as solid particles. In order to get rid of these oxides a flux is used. This is a mixture of various chemicals which at welding temperatures will unite with the oxides to form an easily fusible slag.

Since the oxides of the different metals vary widely in physical and chemical properties, no one flux is suitable for all metals. The following Oxweld fluxes are recommended for use as indicated:

| | |
|---|---|
| Ferro Flux | For fusion welding cast iron |
| Brazo Flux | For fusion welding brass and bronze, and for bronze-welding cast iron, malleable iron, steel, copper, and other metals |
| Cromaloy Flux | For welding chromium alloys such as rustless irons and stainless steels |
| Aluminum Flux | For welding pure aluminum, aluminum alloys, and aluminum castings |

Obviously, the production of a good welding flux requires a knowledge of chemistry at high temperatures as well as experience in welding. It is a good rule to use the prepared fluxes of reputable manufacturers rather than experiment with unsatisfactory substitutes.

## CARBON PRODUCTS

Carbon, in the form of rods, plates or paste, is very useful around a welding shop. Being quite fire resisting and at the same time easy to cut or file into shape, it can be used to control the flow of molten weld metal. For instance, a piece of carbon rod inserted in a hole that happens to be close to the weld, will keep out any molten metal and thus avoid the expense of redrilling. If the hole is threaded, the threads may be completely protected by threading the carbon rod.

Carbon plates, obtainable in various sizes, are particularly useful for backing up holes that are to be welded and for forming molds for rebuilding sections that are missing. Plates filed to approximately the right shape make it possible to build-up the part with but little excess metal at the end, requiring a minimum of machining and finishing.

Carbon paste is a plastic material that can be molded at will and upon drying becomes hard. Like the rods and plates, it

can be used to protect threaded holes or form a mold. Other applications are: To coat and protect machined surfaces from the heat of the flame; to build up a backing where a broken part is missing; or to cushion or support broken sections in alignment (in place of shims).

## MECHANICAL ACCESSORIES

*Welding Table.* Good workmanship is difficult without a suitable place to work. The welding operator needs a table or bench of convenient height and of fire-proof construction. The standard welding table, about 33 in. high, with planed cast iron top supported by an angle iron stand, is very satisfactory. The top is slotted for attaching clamps, V-blocks, and other fixtures. The top may also be made of firebrick set loosely in a frame of angle iron and flat strips.

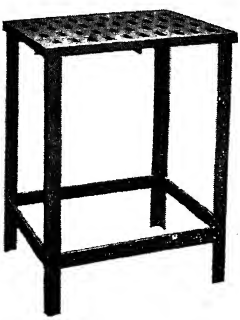


Fig. 31. Standard welding table.

For holding work while welding, a number of heavy clamps should be provided. Mechanics' C-clamps are adaptable to a wide range of work.

For lining up parts, two straight edges and some blocks will be necessary. V-blocks can be obtained from any dealer in machinist's supplies, or, if facilities for machining are available, can be made from a piece of steel about 1½ in. thick, first roughing out with a cutting blowpipe and then machining to correct size and angles.

*Accessories for Chipping and Preparation.* Many methods are in use for beveling the edges of pieces to be welded. Local conditions will determine the choice in any particular shop.

For relatively thin sections, a coarse file or a hammer and cold chisel may be all that is required. Heavier pieces will need an air chisel or a power grinder.

The oxy-acetylene cutting blowpipe affords a rapid, convenient and economical method of beveling steel, wrought iron or cast iron. Its use is discussed in Chapter 36. When cut with the blowpipe, the beveled surface is coated with oxide and frequently bubbles of slag stick to the under side of the

cut. All of this should be entirely removed with a wire brush or grinder before welding.

*Preheating Equipment.* The preheating facilities necessary in any welding shop or department will, of course, depend upon the run of work handled. If much of it requires preheating, it will pay to provide some permanent equipment. If a blacksmith's forge is available, this may do for some work, although care will be necessary to avoid overheating or burning the metal on one side. A small firebrick furnace heated by oil or gas is more satisfactory.

For the occasional casting that is too large for the furnace, a temporary preheating furnace can be built from firebrick as described in Chapter 12. Portable oil-burning preheating torches are frequently used with temporary furnaces.

*Annealing Bins.* After welding, preheated castings must be allowed to cool very slowly in order to avoid setting up internal strains and to prevent hard spots. Where castings have been welded in preheating furnaces, cooling takes place right in the furnace.

For smaller castings, it is well to provide an annealing bin. This is simply a fireproof box filled with some heat-insulating material, such as dry asbestos fibre cement, hydrated lime, Sil-O-Cel, or small bits of used asbestos paper. The hot casting should be quickly buried in this material and left there until cold.

*Finishing Devices.* Almost every job presents a separate finishing problem. A stiff wire brush is very useful for cleaning scale and slag from the weld. Some jobs may need no further work; others may require filing, grinding, drilling or even considerable machining. If consideration is given to this during welding, the amount of excess metal to be removed later can be reduced to a minimum.

## MANIFOLDS

*Oxygen Manifolds.* Where oxygen is required in larger volume than can be conveniently obtained from a single cylinder, or where a centralized oxygen supply is desired, a number of oxygen cylinders can be joined together by means of a manifold.

The five-cylinder portable manifold illustrated may be used for three to five oxygen cylinders, either in the shop or in the field. It weighs only 10 lb. It consists of a hexagonal block with six connections, five for cylinders, the sixth for the regulator. Two caps are provided for closing connections where only three or four cylinders are to be manifolded.

For centralized oxygen supply, stationary manifolds accommodating 6, 10, 20, 30 or more cylinders are used. Duplex

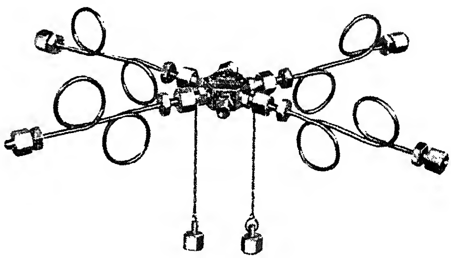


Fig. 32. Five-cylinder oxygen manifold.

construction, each half operating independently, avoids interruption of supply while changing cylinders.

Manifolds should be purchased from and installed by reliable welding apparatus manufacturers familiar with the proper shop practice with reference to manifold construction and installation.

*Acetylene Manifolds.* Where large volumes of acetylene are required, a generator of correct size is generally used. If it is desirable to manifold acetylene cylinders, do so only after receiving the advice of a reliable apparatus company, and after installing special equipment for the purpose recommended by them.

CHAPTER 7

# Setting-Up Apparatus

CHAPTERS 3 to 6 have discussed the functions of the individual items of equipment required for oxy-acetylene welding and cutting. The next step is to learn the correct procedure for assembling them into a unit ready for operation. This is known as setting-up apparatus.

*Welding and Cutting Unit.* A complete welding and cutting unit, consisting of a cylinder of oxygen and a cylinder of dissolved acetylene, together with the necessary apparatus, forms a convenient basis for studying the correct procedure for setting-up apparatus. Such a unit is frequently mounted on a hand truck for portable service. It will be remembered from Chapter 4, page 37, that a cylinder of dissolved acetylene can be used with any type of blowpipe or torch, whether low pressure, medium pressure or balanced pressure.

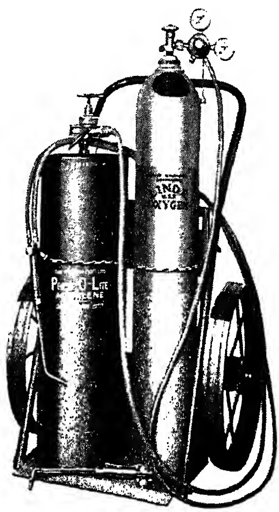


Fig. 33. Welding and cutting unit ready for use.

In addition to the truck, which may or may not be required, the complete welding and cutting unit consists of the following items:

WELDING AND CUTTING UNIT

- Cylinder of oxygen
- Cylinder of dissolved acetylene
- Welding blowpipe
- Cutting blowpipe (or cutting attachment)
- Oxygen regulator
- Acetylene regulator
- Oxygen hose
- Acetylene hose
- Hose connections
- Blowpipe wrench
- Regulator wrench
- Goggles
- Gloves
- Lighter
- Welding rod (usually)
- Flux (if necessary)

Obviously, if the unit is to be used only for welding, the cutting blowpipe or cutting attachment will be omitted. Similarly, if the unit is to be used only for cutting, the welding blowpipe, welding rod and flux will be omitted.

## SETTING-UP APPARATUS

The steps in setting-up apparatus are as follows:

Attach oxygen regulator to oxygen cylinder
Attach acetylene regulator to acetylene cylinder
Connect hose to regulators and to blowpipe
Adjust oxygen and acetylene working pressures
Light blowpipe and adjust flame

The following discussion of these various steps is necessarily somewhat general in character. The exact procedure for certain of the steps (particularly adjusting working pressures, lighting blowpipe and adjusting flame) varies according to the particular type or make of blowpipe used. For this reason, the blowpipe manufacturer's instructions should always be followed. The same applies where sources of oxygen and acetylene other than individual cylinders are used.

The recommendations in sections E, F, G, H, I and J of Chapter 40 should also be studied carefully.

## ATTACHING OXYGEN REGULATOR

Linde oxygen cylinders are readily identified by the marking "This Cylinder Contains Linde Oxygen U.S.P."

*Cracking the Valve.* During shipment or storage some dust and dirt will possibly have collected in the cylinder valve outlet. If the regulator were attached, this dirt would be blown into the regulator and might eventually cause leakage or creeping. To avoid this, stand to one side of the oxygen cylinder and crack the cylinder valve; that is, turn the cylinder valve wheel counter-clockwise just enough to blow out any dirt.* Close the valve quickly to avoid wasting oxygen.

*Connecting Regulator.* Connect oxygen regulator (painted green) to the oxygen cylinder valve outlet. Observe that the threads are right-hand. Tighten the nut with the wrench supplied with the regulator.

*Oxygen valves are designed to open without the use of a wrench. If the valve sticks shut, something is wrong. Notify your superior, and use another cylinder.

*Open Cylinder Valve Carefully.* Make sure that the pressure adjusting screw of the regulator is released, that is, that it is turned counter-clockwise (to the left) until it is loose, before opening the cylinder valve. Open the oxygen cylinder valve slightly so that the high pressure gauge hand moves up slowly. Never open the cylinder valve suddenly, as the rush of high pressure oxygen might strain the high pressure gauge mechanism. After the high pressure gauge hand has stopped moving, open oxygen cylinder valve as far as it will go. The pressure of the oxygen in the cylinder will now register on the cylinder pressure gauge.

## ATTACHING ACETYLENE REGULATOR

Prest-O-Lite acetylene cylinders are readily identified by the marking "This Cylinder Contains Prest-O-Lite Acetylene."

*Blowing Out Dust.* Using the special T-wrench supplied for use with Prest-O-Lite acetylene cylinders, open the cylinder valve one-quarter of a turn and close immediately. This will blow out accumulations of dust in the valve.

*Connecting Regulator.* Connect the acetylene regulator to the acetylene cylinder valve. Observe that the threads are left-hand. Tighten the nut with the wrench supplied with the regulator. If the thread on the cylinder connection is not the same as the thread on the regulator, connect the proper adaptor between them.

Be sure that the connection (or connections, if an adaptor is used) between the regulator and cylinder valve is tight. Test with soapy water. Escaping acetylene can generally be detected by smell.

*Opening Cylinder Valve.* Make sure that the pressure adjusting screw of the regulator is released, that is, that it is turned counter-clockwise (to the left) until it is loose, before opening the cylinder valve. Open the acetylene cylinder valve slowly by means of the special T-wrench. This valve should not be opened more than one and one-half turns, and the wrench should be left in place during the work. The pressure in the acetylene cylinder will then be shown on the high pressure or cylinder contents gauge.

## CONNECTING HOSE

If connections are not yet attached to the hose ends, this should be done next. Use the correct size and style hose connection for the hose to be used. Oxygen hose is colored green; acetylene hose is red. Before using new hose, it should be blown out as described in Recommendation D-4, page 302.

*Oxygen Hose.* Attach an oxygen hose connection nut (right-hand thread) and nipple to the oxygen regulator outlet connection tightly enough to prevent turning of the nipple while the hose is being screwed on.

Cut off the end of the length of oxygen hose square. If the hose has been used before, cut off the end square beyond the mark of the old fitting.

With ferrule type hose connections, push the ferrule on the hose to the shoulder, using water or a soap and water solution for lubrication if the ferrule is tight. Also apply the liquid to the nipple and inside the end of the hose. Screw the hose onto the nipple until the back of the ferrule just clears the nut.

Where hose clamps are used, slip the hose clamp over the end of the hose before forcing the hose onto the nipple until it just clears the nut. Then tighten the hose clamps.

Disconnect this end of the hose from the regulator and attach another oxygen hose connection to the other end of the hose. After the hose connection is attached, connect one end of the hose to the oxygen regulator outlet, if this has not already been done in attaching the hose connections. Be sure this connection is tight.

Now turn the pressure adjusting screw of the oxygen regulator clockwise (to the right) permitting oxygen to pass through the hose. Keep turning the handle until pressure of about 5 lb. per sq. in. shows on the working pressure gauge. Then turn the pressure adjusting screw of the regulator to the left until the flow of oxygen stops. This will blow out dirt from the hose so that it will not be carried into the blowpipe when the hose is connected to it.

*Acetylene Hose.* Attach an acetylene hose connection (the nut has a left-hand thread) to each end of the length of acetylene hose. Connect one end of the acetylene hose to the acetylene regulator outlet. Be sure the connection is tight.

New acetylene hose should be blown out as indicated in Recommendation D-4, page 302. Where acetylene hose that has already been used is being connected up, it will be sufficient to blow through it from the mouth. Do not blow out the hose with acetylene.

*Connecting the Blowpipe.* Connect the oxygen hose from the oxygen regulator to the inlet connection on the blowpipe marked "Oxygen."

Connect the acetylene hose from the acetylene regulator to the inlet connection on the blowpipe marked "Acetylene."

## ADJUSTING THE WORKING PRESSURES

Select the proper welding head, tip or cutting nozzle (according to the chart or table furnished by the apparatus manufacturer) and screw it tightly into the blowpipe.

*To Adjust Oxygen Pressure.* Open the blowpipe oxygen valve only. Adjust the oxygen regulator by turning the pressure adjusting screw to the right until the low pressure gauge indicates the proper pressure as given in the welding and cutting chart, while the blowpipe oxygen valve is open and oxygen is passing through the head or tip. In the case of cutting blowpipes or cutting attachments, the cutting valve must be open while adjusting the oxygen pressure at the regulator. Then close the blowpipe oxygen valve.

*To Adjust Acetylene Pressure.* The procedure for adjusting the acetylene pressure is different for the low pressure and medium pressure blowpipes.

With a low pressure blowpipe, open the blowpipe acetylene valve two turns and turn the pressure adjusting screw on the acetylene regulator to the right until the hand in the low pressure gauge barely leaves the pin. Then immediately close the blowpipe acetylene valve.

With a medium pressure blowpipe, first close the blowpipe acetylene valve. Turn the pressure adjusting screw on the acetylene regulator to the right until the working pressure gauge indicates the proper pressure as given in the welding and cutting chart. Then open the blowpipe acetylene valve and, while acetylene is flowing through the blowpipe, readjust the pressure, if necessary, to exactly the proper pressure as given in the welding and cutting chart. Then immediately

close the blowpipe acetylene valve. This procedure minimizes the amount of unburned acetylene that is released in the room.

## LIGHTING THE BLOWPIPE

In lighting the blowpipe and adjusting the flame, always follow exactly the manufacturer's directions for the particular model of blowpipe that is being used. This is necessary because the proper procedure varies somewhat with different types of blowpipes, and even with different models made by a single manufacturer.

In general, the procedure followed in lighting a blowpipe is first to open the blowpipe oxygen valve a small amount and the blowpipe acetylene valve either fully or somewhat more than the oxygen valve, depending upon the type of blowpipe. The mixture of oxygen and acetylene issuing from the blowpipe tip or nozzle is then lighted by means of the friction lighter.

By further manipulating the blowpipe oxygen and acetylene valves according to the manufacturer's directions for the particular type of blowpipe, the oxy-acetylene flame can be adjusted so as to have the desired characteristics for the work at hand.

The characteristics of the oxy-acetylene flame and various flame adjustments are described in Chapter 8.

To extinguish the flame, first close the blowpipe acetylene valve, then the blowpipe oxygen valve.

## STOPPING WORK

When the welding or cutting is to be stopped for only a few minutes, release the pressure adjusting screws of the regulators by turning them to the left.

When the welding or cutting is stopped for a longer period (during lunch hour or over night) close the cylinder valves and then release all gas pressure from the regulators by opening the blowpipe valves momentarily. Close the blowpipe valves and release the regulator pressure adjusting screws.

If the equipment is to be taken down, make certain that the cylinder valves are closed, that all gas pressures are released from the regulators and that the pressure adjusting screws are turned to the left until free before disconnecting the regulators.

CHAPTER 8

# The Oxy-Acetylene Flame

THE sole purpose of the various items of equipment described in previous chapters is to enable the operator to produce at will an oxy-acetylene flame of the size and character best suited for the work at hand. The oxy-acetylene flame is unique in the fact that its chemical characteristics, and consequently its action on molten metal, can be varied over a wide range. These characteristics are determined by the relative proportions of oxygen and acetylene in the mixture which burns at the blowpipe tip.

This proportion is controlled by the blowpipe oxygen and acetylene valves. The blowpipe valves are consequently not simply shut-off valves to turn the gases on or off; they give the operator complete control of the flame adjustment at all times.

Every operator should be thoroughly familiar with the theory underlying the different flame adjustments as well as with the practical details of how to obtain them.

Chemical reactions that take place when acetylene and oxygen burn are not at all difficult to understand.

*Acetylene Burning in Air.* A chemist would define burning, or combustion, as the combination of some material with oxygen at such a rapid rate that heat (and usually light) are produced. Acetylene will of course burn in air, the oxygen in the air combining with the acetylene to form two new chemical compounds, namely, carbon dioxide and water vapor. To burn 1 volume of acetylene completely, forming carbon dioxide and water vapor, requires 2½ volumes of oxygen.

This may be written in the form of a simple chemical equation

$$C_2H_2 + 2\tfrac{1}{2}O_2 = 2CO_2 + H_2O$$

which means that 1 volume of acetylene ($C_2H_2$) plus 2½ volumes of oxygen ($O_2$) give 2 volumes of carbon dioxide ($CO_2$) plus 1 volume of water vapor ($H_2O$).

In this equation the nitrogen (which as will be remembered from Chapter 2, constitutes 4/5 of the air by volume) has been neglected. This nitrogen does not combine with acetylene, but it is heated by the flame of the burning acetylene. The fact that it is necessary to heat up such a large volume of inert nitrogen greatly lowers the flame temperature.

*Oxy-Acetylene Flame.* Substitution of pure oxygen for air eliminates the nitrogen that must be heated and consequently the flame temperature increases very much. It is not feasible to supply the entire amount of oxygen in the form of pure oxygen from a cylinder, as the resulting flame is not suitable for practical uses. Experience has shown that the best results are obtained when a mixture of 1 volume acetylene and 1 volume oxygen is burned, the surrounding air supplying the additional 1½ volumes of oxygen necessary to complete the combustion.

Accordingly, oxy-acetylene blowpipes are designed to mix oxygen and acetylene in approximately equal proportions.

*Neutral Flame.* When an exactly one-to-one mixture of oxygen and acetylene is lighted at the blowpipe tip, the result-

Fig. 34. Neutral oxy-acetylene flame.

ing flame is called a neutral flame, because there is no excess of either oxygen or acetylene. The neutral flame has a characteristic appearance. There are two sharply defined zones. The inside portion of the flame consists of a brilliant white cone from 1/16 to 3/4 in. long. Surrounding this, is a larger cone or "envelope flame," only faintly luminous and of a delicate bluish color. See illustration, Fig. 34.

The neutral flame is of particular importance to the operator because it is used for such a wide variety of welding and

cutting operations and because it serves as a basis of reference in making other flame adjustments. Consequently, one of the first duties of an operator should be to become perfectly familiar with the appearance and characteristics of the neutral oxy-acetylene flame.

*Chemistry of Neutral Flame.* Since a one-to-one mixture does not contain oxygen enough to burn the acetylene completely to carbon dioxide and water vapor, it causes the following reaction:

$$C_2H_2 + O_2 = 2CO + H_2$$

which means 1 volume of acetylene ($C_2H_2$) plus 1 volume of oxygen ($O_2$) give 2 volumes of carbon monoxide ($CO$) plus 1 volume of hydrogen ($H_2$). It is this reaction that produces the brilliant inner cone of the neutral flame.

In the outer envelope the carbon monoxide and hydrogen (both of which are fuel gases) combine with oxygen from the surrounding air, forming carbon dioxide and water vapor, respectively, as shown in the following two equations:

$$2CO + O_2 = 2CO_2$$

(which means 2 volumes of carbon monoxide plus 1 volume of oxygen from the air give 2 volumes of carbon dioxide) and

$$H_2 + \tfrac{1}{2}O_2 = H_2O$$

(which means 1 volume of hydrogen plus ½ volume of oxygen from the air give 1 volume of water vapor).

It is this combustion of carbon monoxide and hydrogen with oxygen from the surrounding air that forms the bluish flame of the outer envelope.

*Reducing Flame.* When the oxygen and acetylene proportions are varied from the one-to-one mixture, the character of the flame changes very decidedly.

When there is slightly more than this proportion of acetylene in the mixture, the flame will be found to consist of three easily recognizable zones instead of the two existing in the neutral flame. There is still a sharply defined inner cone and the bluish outer envelope, but between these, surrounding the inner cone, is an intermediate cone of whitish color. See illustration, Fig. 35. The length of this intermediate or excess acetylene cone may be taken as a measure of the amount of

excess acetylene in the flame. This flame is variously called an excess acetylene, a reducing, or a carburizing flame. It is used

Fig. 35. Excess acetylene or reducing flame.

in welding steel by the Lindeweld process (Chapter 14), in hard-facing with Haynes Stellite alloy (Chapter 31) and for certain other applications.

*Oxidizing Flame.* On the other hand when oxygen is in excess in the mixture, the flame has the general appearance of the neutral flame, but the inner cone is shorter, is "necked in"

Fig. 36. Oxidizing flame.

on the sides, is not as sharply defined, and acquires a purplish tinge. See illustration, Fig. 36. These are the characteristics of an "oxidizing" flame.

A slightly oxidizing flame is used in bronze-welding (Chapter 18) and bronze-surfacing (Chapter 30), while a more strongly oxidizing flame is used in fusion welding brass and bronze (Chapter 25).

## FLAME ADJUSTMENT

In order to become familiar with the characteristics of the various types of flame and with the adjustments necessary to

obtain them, light the welding blowpipe with the blowpipe acetylene valve wide open and the blowpipe oxygen valve just slightly open.

The acetylene will burn with a smoky yellow flame and will give off quantities of fine black soot.

Now open the blowpipe oxygen valve slowly. The flame will gradually change in color from yellow to blue and will show the characteristics of the excess acetylene flame; that is, there will be three distinct parts to the flame; a brilliant but feathery-edged inner cone surrounded by a secondary cone, and a bluish outer envelope forming a third zone.

With most blowpipes, there will still be a slight excess of acetylene when the blowpipe oxygen and acetylene valves are both wide open and the recommended pressures are being used. Now close the acetylene valve of the blowpipe very slowly. It will be noticed that the secondary cone gets smaller and smaller until it finally disappears completely. Just at this point of complete disappearance the neutral flame is formed.

The operator should practice this adjustment a number of times until he is familiar with this change. It is absolutely necessary that he be able to recognize a neutral flame instantly and to adjust the blowpipe correctly.

In order to see the effect of an excess of oxygen, close the acetylene valve still further. A change will be noted, although it is by no means as sharply defined as that between the neutral and excess acetylene flames. The entire flame will decrease in size and the inner cone will become much less sharply defined.

*To Adjust to Neutral Flame.* Because of the difficulty of making an exact distinction between the excess oxygen and neutral flames, an adjustment of the flame to neutral should always be made from the excess acetylene side; that is, always adjust the flame first so that it shows the secondary cone characteristic of excess acetylene, then reduce the amount of the acetylene until this secondary cone just disappears. Then you will be sure of having a neutral flame.

As stated previously, the neutral flame is the basis of reference for making the other flame adjustments.

*To Adjust Excess Acetylene Flame.* Excess acetylene flame adjustments are usually given in terms of the ratio between

the length of the acetylene cone or "feather" and that of the inner cone, both being measured from the end of the blowpipe tip. Thus, calling the length of the inner cone of the neutral flame adjustment x, a 2x excess acetylene flame adjustment would mean that the acetylene feather should be twice as long as the inner cone. See illustration, Fig. 73, page 122.

Start with the neutral flame adjustment and increase the acetylene until the desired ratio of acetylene feather to inner cone length is obtained.

*To Adjust Oxidizing Flame.* Similarly, the oxidizing flame adjustment is sometimes given as the amount by which the length of the neutral inner cone should be reduced; for example, one-tenth. Start with the neutral flame adjustment and increase the oxygen (or decrease the acetylene) until the length of the inner cone has been shortened the desired amount.

In some cases, as in fusion welding brass and bronze, the exact adjustment has to be determined by the action of the flame on the molten metal.

CHAPTER 9

# Identifying Metals

ABILITY to recognize commercial metals and alloys is obviously an essential part of a welding operator's fund of practical information, for welding procedure varies with the different metals. Metal products in infinite variety are brought to the welding shop. Occasionally the customer may know what the material is, but nearly always he does not. It is up to the operator to identify the metal in order that he may apply the proper welding methods.

There are a number of simple tests that will aid the operator in identifying metals. These are:

*Appearance.* Observe the color, surface characteristics and appearance of a fractured surface.

*Chip Test.* Chip a narrow groove with cold chisel and hammer. Observe the facility of chipping and the characteristics of the chips formed.

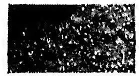
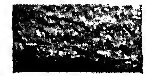
*Spark Test.* Hold a piece of the metal against a power grinding wheel, preferably in a dark place. Observe the color, shape, length and activity of the sparks produced.

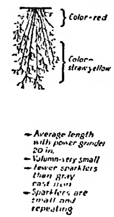
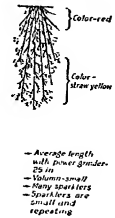
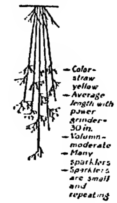
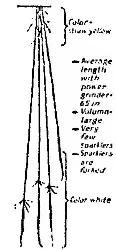
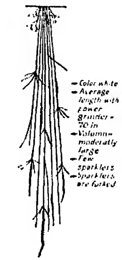
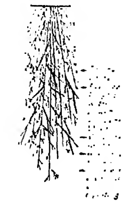
*Blowpipe Test.* Melt the metal with the welding blowpipe flame and observe its behavior.

The chart on pages 74 to 77 gives the results of these tests for a number of the more common commercial metals. With the chart as a guide. the operator should practice these tests with known materials until the characteristic reactions of each metal become part of his general knowledge.

Another useful method, that is not strictly a test, is to question the customer regarding the use of the part to be welded. To the operator with a good background of machine-shop practice, this will give much valuable information, for he will know that certain machine parts are always cast iron, others are usually steel forgings, and so on. These preliminary clues may then be substantiated by the regular tests.

# SIMPLE TESTS FOR IDENTIFYING METALS

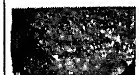
| | | WHITE CAST IRON° | GRAY CAST IRON | MALLEABLE IRON* | WROUGHT IRON | LOW-CARBON STEEL AND CAST STEEL | HIGH-CARBON STEEL |
|---|---|---|---|---|---|---|---|
| APPEARANCE | FRACTURE | Very fine silvery white silky crystalline formation |  dark gray |  dark gray |  bright gray |  bright gray |  very light gray |
| | UNFINISHED SURFACE | Evidence of sand mold; dull gray | Evidence of sand mold; very dull gray | Evidence of sand mold; dull gray | Light gray smooth | Dark gray; forging marks may be noticeable; cast· evidences of mold | Dark gray; rolling or forging lines may be noticeable |
| | NEWLY MACHINED SURFACE | Rarely machined | Fairly smooth; light gray | Smooth surface; light gray | Very smooth surface; light gray | Very smooth; bright gray | Very smooth; bright gray |
| CHIP TEST | APPEARANCE OF CHIP | Small broken fragments | Small partially broken chips but possible to chip a fairly smooth groove | Chips do not break short as in cast iron | Smooth edges where cut | Smooth edges where cut | Fine grain fracture; edges lighter in color than low-carbon steel |
| | SIZE OF CHIP | | $\frac{1}{8}$ in. | $\frac{1}{4}$–$\frac{3}{8}$ in. | Can be continuous if desired | Can be continuous if desired | Can be continuous if desired |
| | FACILITY OF CHIPPING | Brittleness prevents chipping a path with smooth sides | Not easy to chip because chips break off from base metal | Very tough therefore harder to chip than cast iron | Soft and easily cut or chipped | Easily cut or chipped | Metal is usually very hard but can be chipped |

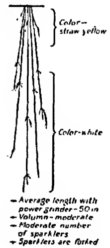
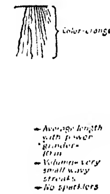
| | FACILITY OF CHIPPING | Brittleness prevents chipping a path with smooth edges | Not easy to chip because chips break off from base metal | Very tough therefore harder to chip than cast iron | Soft and easily cut or chipped | Easily cut or chipped | Metal is usually very hard but can be chipped |
|---|---|---|---|---|---|---|---|
| SPARK TEST | COLOR, SHAPE, AVERAGE LENGTH WITH POWER GRINDER, AND ACTIVITY OF SPARKS ARE DISTINGUISHING DETAILS |  |  |  |  |  |  |
| BLOWPIPE TEST | SPEED OF MELTING (From Cold State) | Moderate | Moderate | Moderate | Fast | Fast | Fast |
| | COLOR CHANGE WHILE HEATING | Becomes dull red before melting | Becomes dull red before melting | Becomes red before melting | Becomes bright red before melting | Becomes bright red before melting | Becomes bright red before melting |
| | APPEARANCE OF SLAG | A medium film develops | A thick film developes | A medium film develops | Oily or greasy appearance with white lines | Similar to molten metal | Similar to molten metal |
| | ACTION OF SLAG | Quiet; tough, but can be broken up | Quiet; tough but possible to break it up | Quiet; tough, but can be broken | Quiet; easily broken up | Quiet | Quiet |
| | APPEARANCE OF MOLTEN PUDDLE | Fluid and watery; reddish white | Fluid and watery; reddish white | Fluid and watery; straw color | Liquid; straw color | Liquid; straw color | Lighter than low-carbon steel has a cellular appearance |
| | ACTION OF MOLTEN PUDDLE UNDER BLOWPIPE FLAME | Quiet; no sparks; depression under flame disappears when flame is removed | Quiet; no sparks; depression under flame disappears when flame is removed | Boils and leaves blowholes; surface metal sparks; interior does not | Does not get viscous; generally quiet; may be slight tendency to spark | Molten metal sparks | Sparks more freely than low-carbon steel |

°Very seldom used commercially.

* Malleable iron should always be bronze-welded.

# SIMPLE TESTS FOR IDENTIFYING METALS

| | | ALLOY** STEEL | COPPER | BRASS AND BRONZE | ALUMINUM AND ALLOYS† | MONEL METAL | NICKEL | LEAD†† |
|---|---|---|---|---|---|---|---|---|
| APPEARANCE | FRACTURE |  medium gray |  red color |  red to yellow |  white |  light gray |  almost white | white; crystalline |
| | UNFINISHED SURFACE | Dark gray; relatively rough; rolling or forging lines may be noticeable | Various degrees of reddish brown to green due to oxides; smooth | Various shades of green, brown, or yellow due to oxides; smooth | Evidences of mold or rolls; very light gray | Smooth; dark gray | Smooth; dark gray | Smooth; velvety; white to gray |
| | NEWLY MACHINED SURFACE | Very smooth; bright gray | Bright copper red color dulls with time | Red through to whitish yellow; very smooth | Smooth; very white | Very smooth; light gray | Very smooth; white | Very smooth; white |
| CHIP TEST | APPEARANCE OF CHIP | ** | Smooth chips; saw edges where cut | Smooth chips; saw edges where cut | Smooth chips; saw edges where cut | Smooth edges | Smooth edges | Any shaped chip can be secured because of softness |
| | SIZE OF CHIP | ** | Can be continuous if desired | Can be continuous if desired | Can be continuous if desired | Can be continuous if desired | Can be continuous if desired | Can be continuous if desired |
| | FACILITY OF CHIPPING | ** | Very easily cut | Easily cut; more brittle than copper | Very easily cut | Chips easily | Chips easily | Chips so easily it can be cut with penknife |

| | FACILITY OF CHIPPING | ** | Very easily cut | Easily cut; more brittle than copper | Very easily cut | Chips easily | Chips easily | Chips so easily it can be cut |
|---|---|---|---|---|---|---|---|---|
| SPARK TEST | COLOR, SHAPE, AVERAGE LENGTH WITH POWER GRINDER, AND ACTIVITY OF SPARKS ARE DISTINGUISHING DETAILS |   | No spark | No spark | No spark | Spark very similar to nickel |   | No spark |
| BLOWPIPE TEST | SPEED OF MELTING (From Cold State) | ** | Slow | Moderate to fast | Faster than steel | Slower than steel | Slower than steel | Very fast |
| | COLOR CHANGE WHILE HEATING | ** | May turn black and then red; copper color may become more intense | Becomes noticeably red before melting | No apparent change in color | Becomes red before melting | Becomes red before melting | No apparent change |
| | APPEARANCE OF SLAG | ** | So little slag that it is hardly noticeable | Various quantities of white fumes though bronze may not have any | Stiff black scum | Gray scum; considerable amounts | Gray scum; less slag than Monel metal | Dull gray coating |
| | ACTION OF SLAG | ** | Quiet | Appears as fumes | Quiet | Quiet; hard to break | Quiet; hard to break | Quiet |
| | APPEARANCE OF MOLTEN PUDDLE | ** | Has mirrorlike surface directly under flame | Liquid | Same color as unheated metal; very fluid under slag | Fluid under slag | Fluid under slag film | White and fluid under slag |
| | ACTION OF MOLTEN PUDDLE UNDER BLOWPIPE FLAME | ** | Tendency to bubble puddle solidifies slowly and may sink slightly | Like drops of water with oxidizing flame will bubble | Quiet | Quiet | Quiet | Quiet; may boil if too hot |

** Alloy steels vary so much in composition and consequently in results of tests that experience is the best solution to identification problems. Stainless steel spark test is shown.

† Due to white or light color and extremely light weight aluminum is usually easily distinguishable from all other metals; aluminum alloys are usually harder and slightly darker in color than pure aluminum.

†† Weight, softness, and great ductility are distinguishing characteristics of lead.

## CHAPTER 10

# Joint Design

IMPORTANCE. As this point is reached, it must be evident that welding requires a thorough understanding of a great many factors in addition to actual welding technique. Of particular importance is the subject of proper joint design for welding. Even the most perfect welding technique may fail to produce a satisfactory result if the joint design is faulty.

It is the purpose of this chapter to outline the simple, fundamental joint designs for welding sheet, plate and pipe regardless of composition. Where modified designs are preferable for certain metals, these are considered in the chapters on the specific metal.

### JOINTS IN SHEET METAL

By trade custom, metal up to 1/8 in. in thickness is considered sheet metal. The fundamental joint designs for welding sheet metal are relatively few in number.

*Butt Weld.* The simplest joint in sheet metal is the butt type weld, Fig. 37. Welds of this general type can be made

Fig. 37. Butt weld for sheet metal.

(1) between two flat pieces of sheet lying in the same plane, (2) between two sheets coming together to form a corner and (3) in rounded sections, such as the longitudinal seam in the shell of a cylindrical tank.

*Corner Weld.* The recommended design for a corner weld, which is simply a form of butt weld, is shown in Fig. 38. This type of weld is widely used in the production welding of sheet metal products, where the parts to be joined are held in correct alignment by means of properly designed jigs or fixtures.

*Flange Weld.* The flange weld, Fig. 39, is also extensively used in sheet metal work, particularly on sheet lighter than 20 gauge. The edges are prepared for welding by simply turning up a flange. The upstanding portion of the flange should extend above the upper surface of the sheet a distance

Fig. 38. Corner weld.

equal to the thickness of the sheet. Flange welds are usually made without adding welding rod. It is important that the operator obtain weld penetration to the bottom of the joint.

*Lap Weld.* The lap weld made along the edge of overlapping sheets is not recommended and *should be avoided.*

The single lap weld, Fig. 40, has little resistance to bending and is consequently quite unsatisfactory for flat sheet. It may

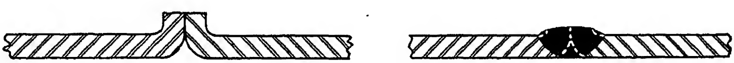


Fig. 39. Flange weld.

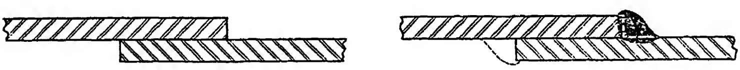


Fig. 40. Lap weld. The second weld necessary to form a double lap weld is indicated by a dotted line.

occasionally be used where, for example, it is necessary to join one cylindrical shell fitting inside another.

The double lap weld, Fig. 40, has better strength characteristics than the single lap, but it requires nearly twice as much welding as the simpler and more satisfactory butt weld.

## JOINTS IN PLATE

For welding, material thicker than ⅛ in. is considered plate. The types of joint recommended for welding depend upon

how the plates to be joined are disposed with relation to each other. The simplest case is, of course, the joining of plates in line with each other. In other cases the plates to be joined may form an angle (usually a right angle) with each other.

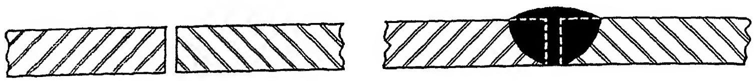


Fig. 41. Open square butt weld.

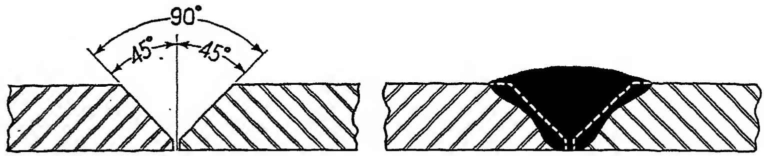



Fig. 42. Open single vee butt weld.

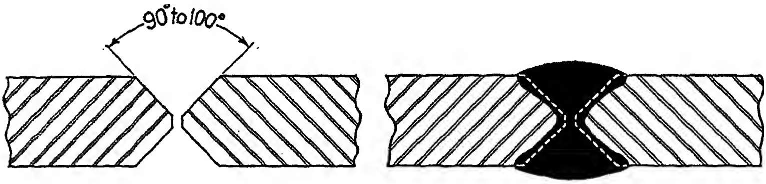



Fig. 43. Open double vee butt weld.

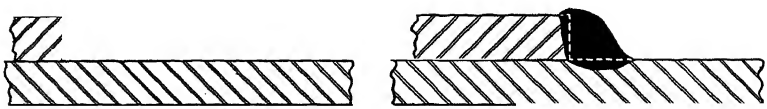


Fig. 44. Fillet weld.

Plate may also meet or intersect a section of pipe; or a pipe or tube may intersect the plate, as in the case of tube sheets.

*Open Square Butt Weld.* For plate 3/16 in. or less in thickness, the open square butt weld (Fig. 41) may be used. The edges of the plate are simply squared accurately; no bevel is required. Before welding the edges are spaced about 1/8 in. apart. The operator should secure thorough fusion completely through to the underside of the plate.

*Open Single Vee Butt Weld.* For plate over $\frac{3}{16}$ in. and up to $\frac{1}{2}$ in. in thickness the open single vee butt weld (Fig. 42) is recommended. The edges forming the joint are each beveled, usually to 45 deg. so as to form a 90 deg. vee. Weld contour and reinforcement should be as indicated in the illustration.

*Open Double Vee Butt Weld.* Plate thicker than $\frac{1}{2}$ in. should, wherever possible, be beveled from both sides so as to form a double vee for welding. The open double vee butt weld is shown in Fig. 43.

For pressure equipment, codes governing the construction of such equipment should be followed.

*Corner Welds.* Corner welds are simply variations of butt type welds which result when the edges of the plates to be joined come together at an angle, as at the corner of a square or rectangular tank. For cylindrical tanks, it is preferable to dish the heads and use standard butt type welds.

Outside corner welds should preferably be designed as shown in Fig. 38.

In rare instances it may be necessary to make a corner weld from the inside. The edges of the plates forming such an inside corner weld should be beveled to aid the operator in obtaining full penetration to the bottom of the weld.

*Fillet Welds.* Fillet welds should be avoided as far as possible in plate work. Fillet welds are used in joining the ends of certain types of flanges or of sleeves to the surface of pipe. The general design is shown in Fig. 44.

## PIPE JOINTS

Pipe joints are essentially similar in design to those for plate.

*Line Joints.* For line joints in pipe, that is joints which do not involve any change in direction of the line, the open square butt weld (Fig. 41) is recommended for pipe having wall thickness under $\frac{3}{16}$ in.; the open single vee butt weld (Fig. 42) for pipe having wall thickness $\frac{3}{16}$ in. and over.

Beveling of the pipe ends for the open single vee butt weld in steel pipe varies according to the welding method used. For neutral flame welding (see page 128) the ends should be beveled 45 deg. to form a 90 deg. vee. For the Lindeweld

process (see page 132) the ends should be beveled 35 deg. to form a 70 deg. vee.

*Branch Connections.* Where the end of one pipe fits into an opening in another pipe, as in the case of branch connections, the edge of the opening should be beveled so as to form a proper vee at all points. The beveling will not be uniform but will vary continuously.

*Turns.* The fabrication of welded pipe turns presents a type of weld design which varies from an outside corner weld at the outer side of the turn to an inside corner weld at the

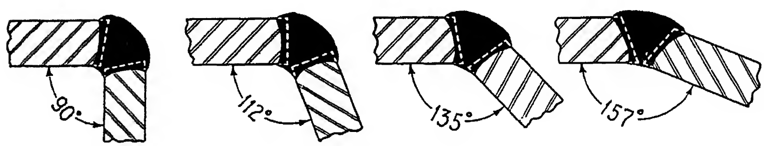



Fig. 45. Outside corner welds on pipe turns.

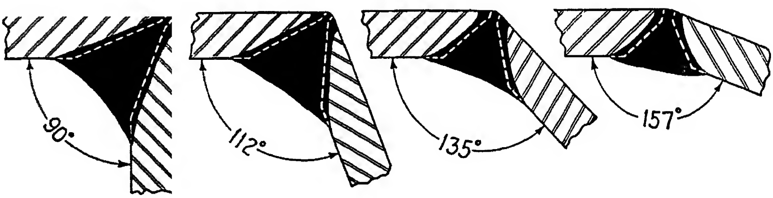



Fig. 46. Inside corner welds on pipe turns.

inner side of the turn. Here again beveling is not uniform but should be done so that the assembled joint will have a satisfactory vee at all points. Figs. 45 and 46 together show the weld sections at the outside and inside of turns of various degrees.

## JOINTS IN CASTINGS

In repair welding of castings, the edges of the fractures are usually beveled so as to form about a 90 deg. vee. Where the metal is very thick and where welding can be done from both sides, a double vee weld is preferable as this type requires only half as much weld metal as a single vee weld for the same thickness.

CHAPTER 11

# Expansion and Contraction

THE practical problems of compensating for the expansion of metal when it is heated by the welding blowpipe, and for the subsequent contraction when the heated metal cools have been subjects of constant study ever since the introduction of the oxy-acetylene process for joining metals. As a result, there have been developed certain precautions or methods of treatment that can be considered as fundamental. A thorough understanding of these constitutes an essential part of the fund of practical information which every operator must possess in order to work efficiently and to carry out intelligently any operation with the blowpipe.

## THEORY

The theory of the expansion and contraction of metals with changes in temperature is based on facts which are easily understood. Heat causes metal to expand and subsequent cooling necessarily means that the heated section will endeavor to contract into its original size and shape. Uneven heating will, therefore, cause uneven expansion, or uneven cooling will cause uneven contraction. Under such conditions stresses are set up within the metal. These forces must be alleviated, and, unless precautions are taken, warping or buckling of the metal takes place. Likewise, on cooling, if nothing is done to take up the stress set up by the contraction forces, further warping may result; or if the surrounding cool sections of the metal are too heavy to permit this change in shape, the stresses remain within the metal itself. Such stresses may cause cracking while cooling or may remain within the metal until further force is applied, as when the piece is put into use.

## SHEET METALS

Due to the fact that sheet metal (1/8 in. and less in thickness) has such a large surface area per unit of weight, heat stresses

tend to produce warping or buckling of the sheet. This and the contraction effect encountered on long seams are the principal points to be considered in sheet metal welding.

### LONG SEAMS

The effect of welding a long seam (over 10 or 12 in.) is to draw the seam together as the weld progresses. The explanation is simple. The spot being welded is melted so rapidly that most of the expansion is taken care of in the molten metal. As the molten spot cools, it contracts and tends to pull the two edges of the seam together. The part previously welded, now cool and solid, resists this action with a consequent hinge effect that pulls the unwelded edges toward each other. If the edges of the seam are placed in contact throughout their entire length before welding starts, the far ends of the seam will actually overlap before the weld is completed.

### SPACING LONG SEAMS

One way of overcoming this effect is to set up the pieces to be welded so the edges are nearly in contact at one end of the seam and separated at the other end a distance that varies according to the metal and its thickness. Some useful data have been compiled that indicate the average spacing allowance per foot of seam:

| | |
|---|---|
| Steel | 1/4 to 3/8 in. per ft. |
| Brass and Bronze | 3/16 in. per ft. |
| Monel Metal | 3/8 in. per ft. |
| Aluminum | 1/5 in. per ft. |
| Lead | 5/16 in. per ft. |
| Copper | 3/16 in. per ft. |

Sheet metal under 1/16 in. in thickness is best handled by flanging the edges, tack-welding at intervals along the seam, and then welding.

### MEANS OF REMOVING HEAT

The means most commonly employed to prevent buckling or warping of sheet metal during welding is to apply the

principle of removing the heat from the base metal adjacent to the weld. In the case of flat seams, a heavy piece of metal such as a section of steel rail or heavy bar stock placed on either side of the seam will effectively prevent the heat from spreading too far and will also tend to prevent movement of the parts by resisting the forces of expansion and contraction.

## JIGS AND FIXTURES

Exactly the same principle is applied in the construction of jigs and fixtures so universally used to hold sheet metal parts in proper position for welding. The clamping action

Fig. 47. Properly designed jigs hold sheet metal parts in alignment and effectively remove heat from base metal.

of the jig prevents undue movement of the parts, while the use of heavy sections in the jig at the desired points will effectively remove the heat from the base metal. In some cases, jigs are water-cooled to increase still further the ability to carry heat away rapidly.

*Use of Wet Asbestos.* Heat may also be removed from metal adjacent to the welding zone by the use of wet asbestos cement

Fig. 48. Observe the spacing and the use of rails in welding a long seam in making a large steel tank.

along either side of each seam. In extreme cases a continuous flow of water can be played over the main body of the sheet.

## PLATE AND FORMED SHAPES

In welding metal of plate thickness (above 1/8 in.), there is somewhat less tendency to buckle or warp, because the greater proportion of metal to surface area tends to diminish the rate of heat flow away from the welding zone. However, in welding long straight seams, the plate should be spaced about 1/4 in. per ft. to allow for the contraction of the seam.

For welding circumferential seams, such as are encountered in pipe, tanks, and pressure vessels, it is obviously not possible to allow a progressively increased spacing around the entire seam. When pipe is lined up for welding, an even spacing of 3/32 to 1/4 in., depending on pipe size, is left between pipe ends. Tack-welds, which are simply short welds about 1 in. in length, are then made at specified intervals to hold the pipe in proper alignment during welding.

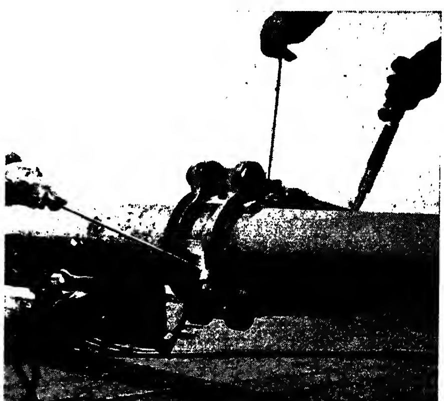


Fig. 49. Clamps used to hold pipe ends in alignment.

For large tanks and pressure vessels, the tack-welds are usually supplemented by a series

of wedge clamps which are progressively removed just ahead of the weld and thus enable the operator to control the seam contraction. The exact procedure is determined largely by experience.

A note regarding cold rolled shapes is of some importance. Because of the stresses that are in the metal shape from the cold working, prior to welding the worked portion of the shape should be heated to a good black heat. This will relieve this strain and there will then be no abnormal stresses to take into consideration while welding.

## CASTINGS

Because of their inherent properties, frequently irregular shape, and generally greater bulk, castings require a more careful consideration of expansion and contraction during welding than do sheet metals or plate.

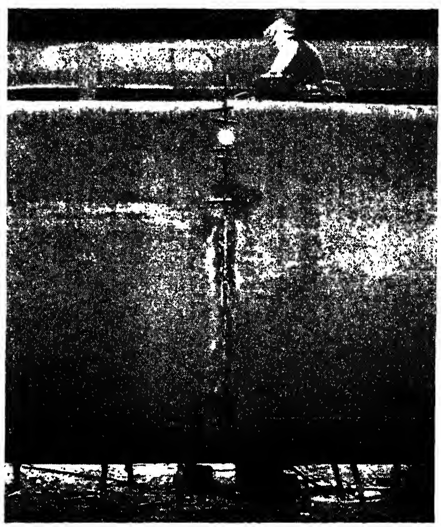


Fig. 50. Wedge clamps control the rate of contraction in welding girth seams.

The following practical suggestions apply primarily to the fusion welding of gray iron castings. Where gray cast iron is bronze-welded or where the metal of the casting is of higher strength, as for example cast steel, the amount of preheating can be correspondingly reduced but the general principles remain the same.

*General Preheating.* Careful preheating of the entire casting to a good red heat is by far the best means of assuring that expansion and contraction of the metal will be even throughout. After welding, a reheating and controlled slow cooling or annealing will assure the welder that all internal stresses are eliminated. It will also be pointed out

in Chapter 20 that preheating and slow cooling are essential factors in assuring proper gray iron structure in the welded casting.

Many castings are small enough so that a temporary furnace is unnecessary, and the welding blowpipe flame can be played over the whole casting to bring it to a red heat. In such cases the welding operation itself is of short enough duration to be completed before the casting loses its red heat. Here again slow cooling is essential to success for elimination of internal stress.

*Local Preheating.* Often only local preheating is necessary or advisable. This is accomplished either in a temporary charcoal-fired furnace (see page 96) built only around the section to be welded, or by playing a preheating torch on the necessary part. Before using this type of stress elimination, it is well to ascertain that parts of the casting that are outside of the heated zone are such that they will not be affected by temporary distortion. That is, the outside section or sections should be of such a shape that when the expansion movement takes place this part of the casting can yield sufficiently without cracking.

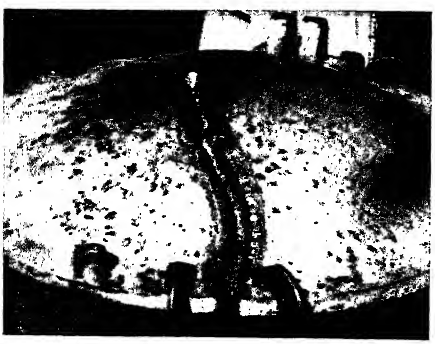


Fig. 51. Drill a small hole beyond the visible end of a fracture such as this.

*Preventing Fracture From Extending.* Prior to welding a fracture that extends in from the edge or from an opening of a casting, it is always advisable to drill a small hole through the casting about ½ to 1 in. beyond the visible end of the fracture. Should the crack start to run when the heat is applied, the crack will go only as far as the drilled hole and stop there. This practice has often saved much work in the case of breaks in very heavy cast iron sections where considerable heat was required.

*Fractures in Complicated Castings.* Fractures of some internal part of a complicated casting require careful study prior

to welding. Such fractures often occur on a section that can be considered as an inner rib, and that is held on either end by a heavier rim or surrounding metal that will check any expansion of the broken part. Total preheating of such a casting is, of course, the best solution to this problem, but this is often impracticable because of the part's location or size. Local preheating will then have to be done. In addition, and this is a most important point, two opposing sections of the enclosing part of the casting will also have to be preheated locally. If this were not done, when the welded section cooled and the metal tried to contract, the already cold outer sections would not give sufficiently, and the welded member would be subjected to a severe tension stress which might cause another fracture, either immediately or after the casting had been placed in service again. Occasionally it may be desirable to accomplish further expansion at necessary points by mechan-

Fig. 52. Jacks are frequently used to expand the break in fractured castings.

ical means such as wedges or jacks. In all such cases it to be remembered that the sole object of such additional expansion of the metal is to leave the casting, when cooled, with a slight compressive stress on the welded part.

*Internal Fractures.* Castings that have a fracture that is entirely contained within a flat plane, such as a crack that does not extend to any edge or opening, usually must be entirely preheated, as there is no other way of relieving the

stresses that would result from a localized heating by the blowpipe followed by contraction on cooling.

Intricate castings often present special problems. Wherever previous experience is lacking, it is advisable to request the expert advice and assistance of an oxy-acetylene service operator.

## NON-FERROUS METALS

Non-ferrous metals, whether in the form of sheet, plate, pipe or castings, require much the same consideration as outlined in the previous discussion, with such modifications as are made necessary by the specfic characteristics of each metal. These points are also considered in more detail in the chapters on the respective metals.

Fig. 53. Certain non-ferrous metals, particularly aluminum, must be carefully supported during preheating.

Several non-ferrous metals and alloys, notably copper, aluminum, nickel and Monel metal, possess a peculiar property known as hot shortness, which means that there is a condition of low tensile strength and low ductility in a temperature range below the melting point.

Monel metal, nickel and high-nickel alloys have a hot short range between the temperatures of 1,450 and 1,650 deg. F. Both above and below this hot short range, these metals regain their normal strength and ductility. Aluminum has a similar hot short range at a somewhat lower temperature.

Because of this property, particular attention must be given to expansion and contraction in welding these metals. Care should be taken to see that there are no undue stresses set up or existent while the weld metal and adjacent base metal are passing through the hot short range as the weld cools, in fact a very slight compression may be desirable. When preheating of these metals is necessary, as in welding castings, provision should be made for properly supporting the part so that it will not distort or collapse in passing through the hot short range.

CHAPTER 12

# Preparation for Welding

PROPER preparation for welding is an important factor in every welding operation.

The edges of the parts to be joined must be prepared in accordance with the joint design chosen (see Chapter 10). The edges must be clean. Arrangements must be made for holding the parts in proper alignment and for preheating, if this is required.

## PREPARATION OF EDGES

The edges of the parts to be joined should be prepared in accordance with the joint design.

For open square butt welds, the edges are simply sheared or cut so that they will match accurately when assembled for welding.

*Flanging.* For flange welds in sheet metal, the edges forming the seam are simply flanged up the proper amount.

Material up to 14 gauge can be flanged by the machines that are a part of every sheet metal shop's equipment. A vise can also be used for small work. Heavier metal can be flanged in bending brakes, presses or special apparatus.

Fig. 54. Beveling a fracture with the cutting blowpipe.

*Beveling.* For open single vee and double vee butt welds, the edges should be beveled so as to give the desired angle or vee. For single vee welds, the bevel should not extend entirely through the plate or pipe wall. An un-

beveled shoulder 1/16 in. or slightly less should be left at the bottom of the vee.

The oxy-acetylene cutting blowpipe can be used to advantage in beveling the ferrous metals, steel, cast iron, and certain alloy steels.

Beveling can also be done by the use of pneumatic chipping hammers, by grinding, by machining, or by other suitable means.

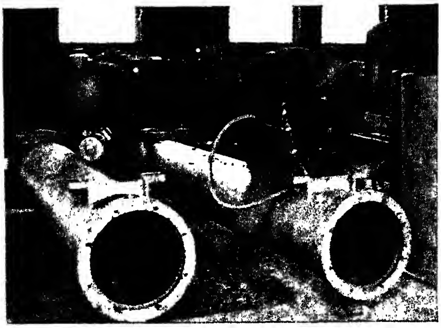


Fig. 55. Chipping and grinding are also used to prepare the edges for welding.

Pipe, for example, can be purchased in standard lengths with the ends machine beveled for welding.

## CLEANING

Preparation for welding also involves making certain that the edges of the joint are thoroughly clean.

Oil, grease, paint and dirt of any kind must be removed. Oily and greasy materials can be removed by washing with gasoline or by burning off with the blowpipe flame. A wire brush or grinding wheel will remove other materials.

Where beveling has been done with the blowpipe, any globules of cutting slag should be knocked off. It is not necessary, however, to remove the adherent blue-black film of oxide on the cut surface, as this does not interfere with welding.

## ALIGNMENT

With the edges properly prepared for welding, the next consideration is the steps to be taken to make certain that the finished job will be in correct alignment. The accuracy of alignment required varies, of course, with different types of work, being greatest where the part has several shaft bearings or similar openings which must line up exactly in the finished job.

The practical methods of maintaining alignment are based on the principles discussed in Chapter 11.

*Tack-Welds.* Joints such as flange joints in sheet metal are frequently held in alignment for welding by simply tack-welding at intervals along the seam. Tack-welds are simply short welds, usually about 1 in. in length. Depending upon the method of welding, they are either melted out and rewelded as they are reached in welding or they become a part of the finished weld.

Tack-welds are also extensively used to hold pipe joints in alignment for welding. For line joints, special clamps are usually placed over the ends of the pipe before tack-welding to assist in accurate line up. The pipe ends are also spaced a predetermined amount before tack-welding.

*Bars.* Lengths of bar iron are frequently used to space sheet metal for welding. These are placed parallel to the seam half an inch or so back from the joint after the sheets have been spaced properly and clamped down if desired. The weight of the bar not only minimizes distortion but also helps to control the speed with which the far ends of the seam are brought together by the heat of welding.

Heavy bars, strips of heavy plate, or other bulky sections of iron or steel placed along the seam will also reduce the tendency to distortion by conducting some of the heat out of the sheet. For production welding of sheet metal articles, use is frequently made of work holding devices consisting of specially cast members (sometimes hollow and water-cooled) or of sections of plate in which beveled slots are cut.

*V-Blocks.* Bars, tubing, shafting and small diameter pipe can be lined up by the use of accurately machined V-blocks.

*Clamps.* In many instances, proper alignment can be secured by the use of C-clamps, H-clamps, wedge clamps or other clamping devices.

Sometimes a spring is incorporated in a clamping device to permit expansion and contraction of the clamped part during preheating and cooling.

*Jigs.* Where a number of similar parts are to be welded, it is advisable to consider the use of a specially designed jig, fixture or other work-holding device.

Jigs embrace every degree of complexity from a spacing fixture to motor-driven jigs so arranged that the work passes

before the operator at a speed consistent with the speed of welding.

The simpler jigs act as a gauge, spacing the parts and holding them in the correct relative positions until they are welded.

In more complicated designs, such as the movable or swinging jig, the work, locked tight, can be moved as welding progresses so that the parts are kept constantly in the handiest position for welding. Examples of this type are the supporting rollers often used to rotate the work when welding the circumferential seams in round tanks, and jigs for holding door frames and sash which must be welded at the four corners.

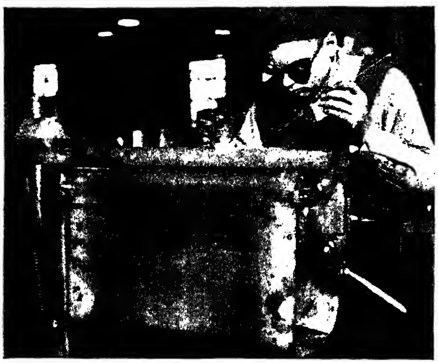


Fig. 56. Jigs facilitate production welding operations by keeping the parts in correct alignment.

PREHEATING

Where preheating is required, the method to be used should be determined in advance and all preparations made so that welding will proceed without interruption. The reasons for preheating have been discussed in Chapter 11. The following paragraphs give practical suggestions on preheating practices.

Various types of apparatus and agencies are employed for preheating, depending of course, upon whether the preheating is to be general or purely local.

*Preheating With Blowpipe.* The simplest form of local preheating is that which is accomplished by the oxy-acetylene blowpipe flame itself. If the part to be welded is small and the ends free to expand and contract, it is only necessary for the welder to play the blowpipe flame over the metal around the part to be welded before the actual welding is done.

*Forge.* If a forge fire is available, it provides a very convenient means of preheating metal. Care must be taken, however, that the blower is used only enough to keep the fire

going and that too much heat is not applied to the metal. Use of an asbestos paper covering is advisable to protect the metal from any possible drafts.

*Preheating Torches.* Many types of preheating torches are available which burn inexpensive fuels such as kerosene, fuel oil, natural gas, or city gas. These may be used to accomplish local preheating on large pieces of metal, and, if used in a furnace so that they do not play directly upon the metal, they may be used for general preheating.

Fig. 57. Gas preheating torch (at right) in use while welding an aluminum crank case.

*Permanent Furnaces.* For general preheating where many similar large castings are to be welded special permanent preheating furnaces are employed. Preheating furnaces of this type are usually fired with either natural or city gas, as the gas flame is so easily controlled. Fig. 58 shows a permanent preheating furnace used for preheating a regular run of cast iron, steel, and aluminum castings.

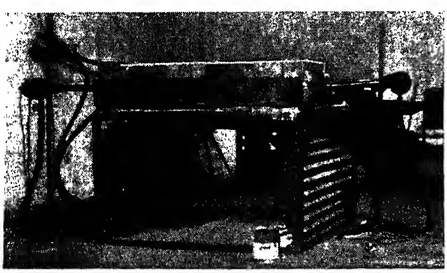


Fig. 58. Permanent type of preheating furnace heated by gas torches.

*Temporary Furnaces.* The most common preheating agency for general preheating is the temporary firebrick furnace, fired with charcoal. Charcoal is a most effective preheating fuel as it requires no forced draft to burn and its combustion will give a steady, constant temperature. No soot or smoke is given out, which might deposit on the metal and hinder the welding operation. Temporary firebrick furnaces are sometimes fired with gas, oil, or kerosene preheating

torches instead of the charcoal. Coke should not be used as a fuel, as it gives too high a temperature and too localized a heat.

*Building a Temporary Furnace.* The temporary brick furnace is constructed by laying the bricks up around the casting,

Fig. 59. Starting to build a temporary preheating furnace. The pipe cradle supported the part to be preheated.

allowing enough space between the brick wall and the casting for the fuel and to permit handling the casting if turning is necessary during welding. The lower tiers of the bricks are set with air spaces between them so that the right amount of air may get into the furnace to insure the proper combustion of the fuel. Figs. 59 and 60 show the details of building a temporary brick preheating furnace using charcoal as fuel.

The design of a temporary furnace will vary with each piece to be preheated, depending upon the size, thickness and type of metal. For instance, with very large and heavy castings it may occasionally be necessary to use more than one thickness of brick in making the wall of the furnace. The most usual covering for a temporary brick preheating furnace is a sheet of asbestos paper supported on bars or light angle iron placed across the top of the furnace. Several small holes are punched in the paper to allow for the escape of the products of combustion. The section of the metal to be welded should be near the top of the preheating furnace, so that when

the proper temperature has been reached in the preheating, the asbestos paper covering may be drawn back sufficiently to permit the welding to be carried on while the metal remains within the furnace, Fig. 61. After the weld is finished, this covering may be put back over the whole furnace to protect the metal from sudden cooling.

Fig. 60. Temporary ating furnace with charcoal lighted.

## SEQUENCE OF OPERATIONS

For large and complicated jobs, such as a casting with a number of fractures, it is advisable to give careful study to the proper sequence of operations. This involves consideration of the location of the fractures with reference to each other, the probable effects of expansion and contraction and the methods of assuring proper alignment.

Such preliminary study will indicate how preheating should be done and the order in which the fractures should be welded. The time spent in determining such a sequence of operations in advance will be well repaid by the simplification of subsequent welding operations.

As some experience is required to do this properly, it is advisable to obtain the assistance of an oxy-acetylene service operator before attempting such work for the first time.

Fig. 61. Welding is done through an opening in the asbestos paper covering.

# CHAPTER 13

# Welding Sheet Steel

GENERAL *Distinction Between Various Alloys of Iron.* Iron and steel are the most important industrial metals. As a result of the work of modern metallurgists, users of iron and steel products have at their disposal a wide range of ferrous (ferrous means iron) materials, varying in chemical and physical properties, to meet all service conditions. It is quite important that the welding operator should be able to recognize the more important varieties of iron and steel.

Wrought iron and ingot iron, the purest of commercial irons, contain very little carbon, less than 0.05 per cent. They are comparatively soft and ductile, having a tensile strength of about 45,000 lb. per sq. in., and they melt at a temperature of about 2,700 deg. F. As the carbon content increases, the product becomes harder, but more brittle, the tensile strength increases up to a certain limit, and the melting temperature decreases. The products known as steel come within this range, beginning with "dead soft" steel (about 0.10 per cent carbon) passing through "mild", "medium", and "rail" steel up to the tool steels. Commercial steels stop in the very high carbon tool steels containing about 1.50 per cent carbon.

*Nature of Cast Iron.* At about 2.50 per cent carbon, the products become so brittle that they cannot be rolled or worked like steel but must be cast to shape in molds. The range from about 2.50 to 3.50 per cent carbon includes the commercial cast irons, the characteristic properties of which are discussed in Chapter 20.

*Alloy Steels.* In addition to the carbon steels mentioned above, there are special steels or alloy steels which contain considerable amounts of other metallic elements, such as chromium, manganese, silicon, nickel, tungsten, and vanadium, and whose special properties are procured only after a heat-

treatment of more or less precision and complexity. These are considered in Chapters 21 and 22.

## WELDING CHARACTERISTICS OF STEEL

Steel melts at from 2,400 to 2,700 deg. F., depending upon its chemical composition. It does not melt rapidly. Fusion is confined to a small area directly under the welding flame. The metal is not very fluid until it gets hot—that is to say, there is a soft or "mushy" range between the solid state and the liquid state. This is of great practical value in welding as it is one of the important factors permitting full control of the weld metal, especially when welding a vertical joint or directly overhead. (In this connection, reference should be made to the more complete discussion of puddle control factors on page 126.)

*Fusion Welding of Steel.* To a large extent the strength of the weld depends upon the thorough union or bonding of all parts of the weld metal to itself and into the beveled edges of the pieces being welded. A common fault of the unskilled or careless workman is to force the molten metal ahead of the welding area and allow it to adhere to or chill against the colder sides of the beveled edges. Avoid this at all costs! A true fusion weld is not produced in steel until it actually melts.

*Work Slag to Surface.* At dull red heat, steel exposed to the air begins to oxidize; a form of rapid rusting. As this oxide melts at a temperature lower than the metal, most of it remains at the surface. Care must be taken to work all oxide to the surface, for its presence mixed with the final weld metal is very harmful. The oxide or scale remaining on the surface of the completed weld can be easily removed by wire brushing or hammering, just before the weld gets cold.

## WELDING METHODS FOR SHEET STEEL

*Definition of Sheet Steel.* A considerable percentage of steel produced is rolled out into flat plates of various thicknesses. It is customary to make a distinction between steel plate and sheet steel. The exact dividing line varies somewhat in the different branches of the metal products industry, but

where welding is concerned, metal ⅛ in. (11 gauge) or less in thickness is called "sheet."

*Welding Methods.* Sheet steel may be joined by fusion welding or by bronze-welding.

## FUSION WELDING OF SHEET STEEL

As discussed in Chapter 10, not all joint designs for sheet metal require welding rod. Where welding rod is used, it is most important to select only high quality rod.

*Welding Rod.* For high strength fusion welds in sheet steel, Oxweld No. 1 H.T. (High Test) Patented Steel Rod is recom-

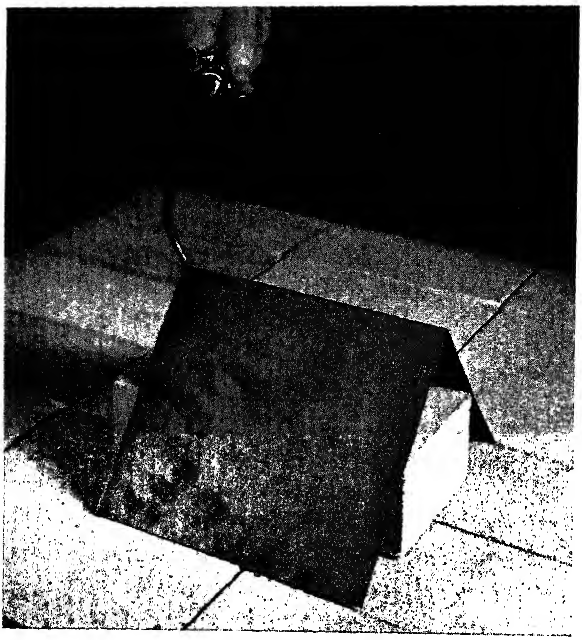


Fig. 62. Practice corner weld.

mended. It will consistently produce welds having tensile strengths about 11,000 lb. per sq. in. higher than welds made with ordinary steel rods.

Where high tensile strength is not a factor, Oxweld No. 7 Drawn Iron Rod is recommended. Although welds made with

this rod do not have the extremely high tensile strength of welds made with High Test rod, they are sufficiently strong for all ordinary purposes and have a high degree of ductility.

*Blowpipe Manipulation.* Before starting to make actual welds, the learner should become familiar with the "feel" of the blowpipe by simply melting the surface of a piece of sheet.

Take a piece of sheet steel about 6 in. square and place it flat on the welding table. Fit the blowpipe with a welding head or tip one size smaller than that recommended in the manufacturer's table for that thickness of metal. Put on goggles. Light the blowpipe and adjust the flame to neutral.

Hold the blowpipe with the head or tip inclined at an angle of about 60 deg. to the surface of the sheet so that the flame points ahead along the line of weld. With the tip of the inner cone of the flame about 1/8 in. away from the sheet, move the blowpipe along in a straight line across the sheet slowly enough just to melt the sheet without burning a hole clear through. Just before the edge of the sheet is reached, hold the blowpipe still until a hole is burned through the sheet. Observe how rapidly the steel melts and flows. Continue this practice until thoroughly familiar with the action of the flame on the metal.

## PRACTICE CORNER WELD

Obtain a few pieces of sheet steel; scrap pieces may of course be used, but they should be brushed free from dirt or rust, and fairly flat so edges will match together.

*Making the Joint.* Begin by setting up two pieces of light material (perhaps 20-gauge metal) over a firebrick in the form of a tent (about a 60-deg. angle) with the top edges just touching, Fig. 62. These pieces should be about 6 by 8 in. Weld along the long side. Do not space the edges at the far ends; simply place them so the sheets are just touching all along the corner. This is really a type of corner weld, see page 78.

Fit the welding blowpipe with the tip or welding head recommended for work on that thickness of sheet. Put on goggles, adjust the flame to neutral and begin at one end, holding the blowpipe as explained above. Merely melt the two edges together. To do this, apply the flame to the edges,

moving it along fast enough to fuse the edges without burning a hole between. Work carefully and steadily to see that the sheets are melted to the bottom and are fused together all the way to the under side.

It may take some practice to avoid burning holes between the edges, but if you feel the metal is melting too rapidly, simply flip the flame away momentarily and allow the puddle to solidify slightly before going ahead. Be sure you do not work so fast that melted metal is blown ahead on cold edges.

*Testing the Joint.* When this weld is finished, see how good it is. Set the little metal tent up on a flat surface and flatten it by hammering on the top. When this is done, turn it over and look at the weld from underneath.

If the weld cracks open and exhibits places where the original edge of the sheet is still to be seen, it indicates that you have not melted the edges to a sufficient depth, or that you have blown molten metal ahead. If the weld breaks, learn why this happened and make another weld, avoiding your first difficulties. It may be that the blowpipe was not properly adjusted and that you "burned" the metal in the weld with an excess of oxygen. This will show by very coarse, glittering crystals, frequently having peacock colors.

If your first weld proved to be a good one and hammered down flat without cracking either on the top or the bottom, try again and see if you can make another good weld the same way.

## PRACTICE BUTT WELD

When you have made a good corner weld several times in succession, obtain two pieces of 16-gauge ($1/16$ in.) sheet about 8 in. long, and place them flat on the welding table with the edges just touching, Fig. 63. A firebrick or a piece of steel bar may be placed on each piece far enough from the edge so as not to interfere with your work.

Adjust the welding blowpipe with the proper head and oxygen pressure and weld the seam from end to end. Move the blowpipe along in a straight line at just sufficient speed to fuse the edges together thoroughly. Be sure to fuse the metal through to the bottom of the sheet.

Do not be disturbed if the finished weld is depressed a little

below the surface of the two sheets. Even on a very good weld it probably will be; but in this exercise, the principal thing is to secure complete penetration between the edges. To find out whether or not you have done this, turn the weld over after it is completed and look at the under side. There should be some small rounded beads but all traces of the crack between the edges should be gone.

*To Test the Joint.* When you can make a weld of this sort, clamp it in a vise or along the edge of an anvil and hammer the piece down by striking the sheet on the top side. A good weld will bend through 90 deg. without difficulty. You should

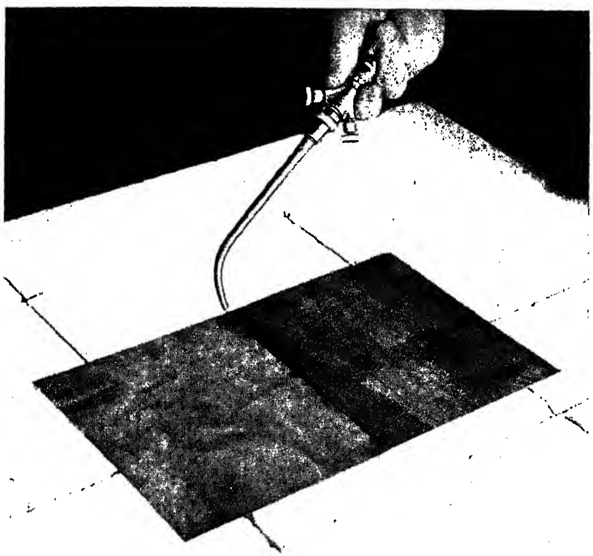


Fig. 63. Practice butt weld.

also be able to hammer the test weld down flat without breaking it.

If the weld does break, examine it carefully and see whether or not you have fused the edges together for the full length of the seam, or whether it has been overheated in spots. Then repeat the exercise until you have mastered the technique.

## PRACTICE WITH WELDING ROD

After practicing the above exercises until able to make a good weld, try the same thing using a $\frac{1}{16}$ in. steel welding rod. Hold the tip of the rod so it touches the puddle of molten metal as it melts. Never hold the rod so that it drips, drop by drop, into the weld. By fusing the welding rod into the weld as you go along, you can build up the weld to the surface of the sheet. Welds on light sheet metal are usually made just flush in this way, for appearance. In making the corner weld, be sure to add enough metal from the welding rod so that a

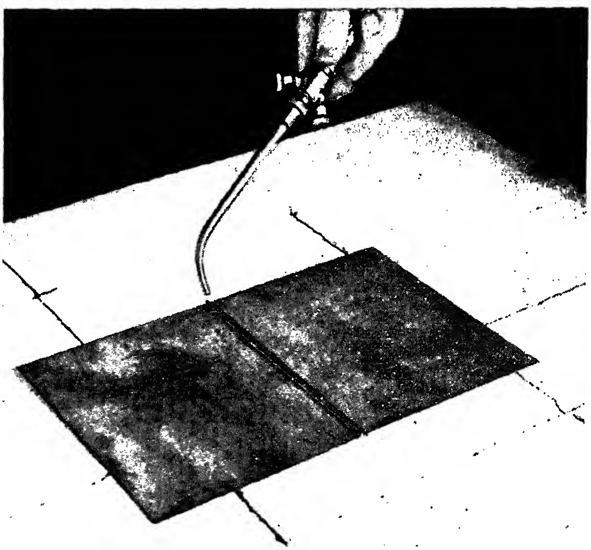


Fig. 64. Practice flange weld.

full corner is formed. This is a most important point in fabricating sheet metal products, such as gear guards, in which corner welds are used.

When you first begin to use welding rod, you may be inclined to work too fast and melt the rod between the edges before these are properly melted through to the bottom of the sheet. A weld of this sort will break when hammered in the vise.

## PRACTICE FLANGE WELD

When you can make a good weld in 16-gauge sheet, both with and without welding rod, and both a butt weld and a corner weld, try making a flange weld on a piece of 24-gauge metal.

*Preparation of Joint.* To do this, turn up a very thin edge along one side of two pieces of the sheet. The flange can be turned over the edge of a steel plate, or in any other way that is convenient. The height of the flange above the surface of the sheet should not be more than the thickness of the sheet; if higher, shear off the extra metal. Put the two flanged edges together so the flange stands up, and weld from one end to the other by melting down and fusing the flanges.

No welding rod will be needed. It is a little more difficult to secure fusion to the under side in this kind of a weld because you have so much more metal to melt down, but it can be done without burning holes through when you acquire sufficient skill.

*Testing.* Such a weld should be tested in the same way as the previous type.

If your first weld does not work out properly, try again until you are able to make a good one, using this design of weld (which, by the way, is very popular in large scale production work in sheet metal).

## PRINCIPAL POINTS FOR LEARNERS

After completing this short series of practices you will have learned several things about sheet metal welding.

You will know how to make three types of welds common in sheet metal work. In working down to the bottom of the sheet, you have learned to secure "penetration," which in all welding is very important indeed. You have also observed by testing your welds and noting their defects, how to secure thorough fusion—a complete union of the melted edges of the two sheets.

By practice and testing you can thus learn to make good welds even though the first efforts may be far from satisfactory.

And from the entire series you will be able to appraise the value of testing your work to make sure that you are securing welds of the highest possible quality.

## PRACTICE ON LONG SEAMS

Having mastered the welding of short lengths, the student should next attempt continuous welds, 18 to 24 in. long. For the reasons given on page 84, the pieces should be set up with the edges nearly in contact at one end while at the other end they are separated ¼ to ⅜ in. Start welding at the end where the sheets are almost in contact. As the weld progresses, the sheets will draw together, and if the spacing is correct the far ends of the seam will just meet as the weld is completed.

Spacing is used in welding practically all sheet and plate where seams of any length are made. The exact spacing varies with such factors as thickness of metal and speed of welding, so the exact spacing must often be determined by experiment. For sheet metal work, the spacing may vary from one to six per cent of the length of the seam.

Fig. 65. Ingenious swivel-type jigs facilitate production welding of intricate assemblies.

*Jigs.* In most sheet metal work it is necessary to hold the parts to be welded in the correct position by means of some sort of clamping device. Where a large number of identical articles are to be made, welding is done in a jig. This is simply a device for holding the work, designed particularly for the article being produced.

*Tack-Welds.* Where the amount of work does not warrant the construction of a jig, the parts may well be set up in position and "tack-welded" together. Tack-welds are simply very short welds (for sheet metal, not more than ½ in. long) made at intervals along the seam to hold it firmly in position. During welding these tack-welds should be melted out with the flame and re-welded.

*Prevention of Buckling.* If buckling occurs in welding flat sheet, it may be overcome by placing a heavy piece of metal on either side of the seam. A section of a steel rail or a heavy steel bar placed parallel to and about 1 in. back from the seam will often correct the difficulty.

Heat may also be removed from metal adjacent to the welding zone by the use of wet asbestos cement. If this dries out during welding, more water should be added. In extreme cases a continuous stream of water may be played on the body of the sheet, using a dam of asbestos cement to prevent the water from running into the welding zone.

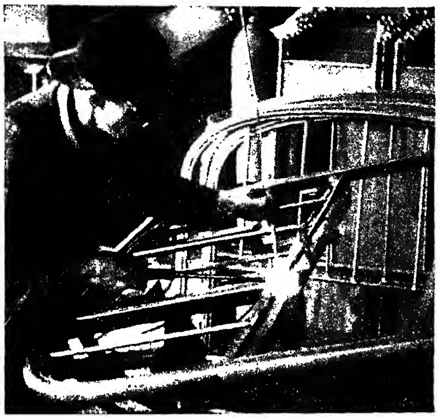


Fig. 66. Bronze-welding is extensively used in the manufacture of metal furniture.

## PRODUCTION WELDING

An enormous number and variety of sheet metal products in many industries are fabricated by welding. Typical examples are the production of welded tanks, gear and machine guards, ventilators, utensils, metal furniture, refrigerators, door and sash frames, automobile bodies and other automotive parts.

## BRONZE-WELDING SHEET STEEL

Bronze-welding, described in detail in Chapter 18, is frequently used in fabricating articles from sheet steel.

*Welding Rod.* Oxweld No. 25 M. Patented Bronze Rod is recommended for bronze-welding sheet steel.

For bronze-welding sheet steel in the manufacture of metal furniture and similar products that are painted or enameled after welding, Oxweld No. 19 Cupro Rod is extensively used. This is a special copper alloy rod, free from zinc. As no flux is required with this rod, its use solves a troublesome

problem as certain paints and enamels will not adhere to a surface that has been fluxed.

Where the surfaces to be joined are clean and bright, Oxweld No. 25 M. Bronze Rod can also be used without flux.

*Bronze-Welding Technique.* For bronze-welding sheet steel, the standard bronze-welding technique described on page 145 should be used.

Essentially the same technique is also used when bronze-welding with Oxweld No. 19 Cupro Rod except that no flux is required.

## CHAPTER 14

# Metallurgy of Steel Welding

BEFORE proceeding to a consideration of the welding of steel plate, it is pertinent to study the improvements in steel welding that have resulted from comprehensive metallurgical investigations during recent years.

Oxy-acetylene welding of steel involves heating the metal from room temperature up to and beyond its melting point and hence in a metallurgical study of the process it is necessary to consider all of the effects—physical, metallurgical and chemical—that can take place in steel over the entire temperature range both in the solid and liquid condition. The fact that welding usually progresses along a joint or fracture and that surrounding the point of welding all temperatures are present from normal to that of liquid metal, adds greatly to the difficulty of accurate metallurgical study of the system.

### DECARBURIZING EFFECT OF OXIDE

From the point of view of the weld metal, one of the most important metallurgical considerations involves the reaction between iron oxide and carbon.

As is well-known, steel reacts with the oxygen of the atmosphere at all temperatures. At ordinary temperatures the reaction so commonly recognized in rusting takes place slowly. At higher temperatures the tendency for iron to react with oxygen markedly increases, resulting in an adherent oxide scale which affects greatly the steel just below the surface. At the junction of scale and steel, the carbon of the steel begins, when heated, to react with the oxide of the scale, first at the surface, the carbon being converted to a gas and thus eliminated. As the surface of the metal becomes decarburized, more carbon from below the surface migrates through the solid steel to the decarburized surface, carrying on this reaction still further so that in the course of a relatively short time, the carbon may be almost completely removed from the steel to an appreciable depth.

When the metal becomes molten, all these reactions can take place at an even faster rate. Iron oxide becomes soluble in the liquid and hence is in a condition to react much more rapidly with carbon and certain other elements contained in the molten steel.

*Rimmed Steel.* This reaction is well known to the steel maker and is utilized in open hearth steel practice in the production of the type of steel known as rimmed steel. When this type of steel is tapped from the furnace it contains a definite amount of iron oxide in relation to its carbon content. In the ingot mold there is a gentle effervescing due to the reaction between the oxide and carbon contents of the liquid steel which results in an ingot with an exceedingly clean and dense surface but filled with cavities or blowholes toward its center. Such a steel is well adapted to the production of many articles which must have a good surface.

The strength and other physical properties that this type of steel can have even when perfectly made are strictly limited by the fact that only low carbon steels can be rimmed and the presence of alloying elements is prohibited by the nature of the operation.

*Practice for High Grade Open Hearth Steel.* If steel is required having higher physical properties than it is possible to obtain from rimmed product, the open-hearth process is changed accordingly. At the proper time the reaction between iron oxide and carbon is stopped by the addition of 15 per cent ferrosilicon and spiegel or silico-manganese. The silicon and manganese of these additions reduce all of the iron oxide of the steel bath and when the additions are properly made, the solid products of the reaction, manganese oxide and silica, effectively flux out the last of the impurities in the bath. Additions are then made to bring the steel to the desired analysis.

When such a steel is cast into the ingot mold, it lies quiet and freezes first against the ingot mold and from there inward to the center. Since with such a deoxidized or killed steel there is no gas evolution to form blowholes, the shrinkage in volume during the freezing operation results in a pipe or cavity in the center of the top of the ingot but the balance of the ingot is exceedingly dense and solid.

## WELDING WITH LOW CARBON STEEL RODS

The first oxy-acetylene welding of good quality was done with low carbon steel welding rods containing a minimum of other elements. The operation is quite analogous to the making of rimmed steel. In the heating-up of the base metal and the welding rod to the fusion point, both become coated with iron oxide, or scale. Several effects resulting from this fact have a direct bearing on the manipulation during welding and on the quality of the finished weld.

First, the scale on the surface of the metal melts at a lower temperature than the steel itself, hence must be removed from the surface in order to get adhesion between the added metal and the base metal. The endeavor to be certain that this had been accomplished led to the melting of a considerable amount of base metal, giving a wide weld and excessive consumption of welding gases.

Also, in order to make sure that this liquid iron oxide was completely eliminated from the weld, it was necessary to carry the temperature of the metal well above its melting point in order to obtain the liquidity that comes with higher temperatures.

Further, the oxide dissolved in the metal reacted to some extent with the carbon, giving rise to blowholes, and the complete absence of silicon, manganese, and other deoxidizing elements prevented a cleaning action such as goes on in an open-hearth furnace during the manufacture of high grade steel. The carbon content of the rod had to be low to avoid excessive reaction between it and copious amounts of iron oxide that were present, which would have led to a serious number of blowholes in the weld. The scale on the surface of the base metal effectively decarburized the rod metal, still further lessening the amount of strength-giving carbon in the weld. The sluggish flowing qualities of the substantially pure iron weld metal led to the ripple type of weld since the metal had to be blown into place.

In spite of all these difficulties and what now seem like welds having a very low order of strength, these welds served the early days of industry well.

## MODERN STEEL WELDING RODS

With growth of the welding industry and increased knowledge of its needs came realization of the important role played by the rod aside from that of simply supplying metal to fill the scarf or vee. Rods were devised containing the elements on which the steel manufacturer relies for the production of high grade steel. By the addition of silicon and manganese the gas-forming reaction between carbon and iron oxide was minimized and replaced by a reaction between iron oxide and these metallic elements. Since the products of the reaction are solid, they do not result in blowholes and with the proper balance between the silicon and manganese contents in the welding rod, the ratio of silica to manganese oxide is controlled so as to produce a fluid slag which readily floats to the surface of the metal, effectively cleansing the weld metal as it does so and blanketing it against further oxidation. Eliminating the causes of the carbon-iron oxide reaction makes it possible to increase the carbon content of this type of rod and consequently of the weld metal to a figure comparable to the usual structural steel.

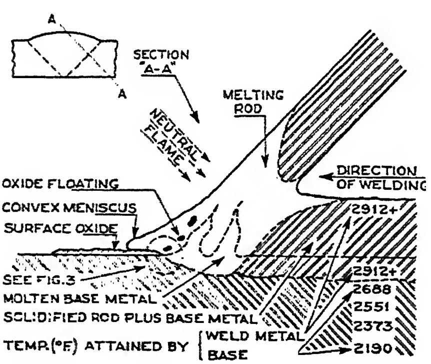



Fig. 67. Sketch indicating metallurgical factors in neutral flame welding.

As a consequence this type of rod yields materially higher strength as well as sounder welds. The strongly reducing elements in the rod remove the scale on the base metal without leading to further troubles thereby presenting a clean surface for the weld metal to adhere to, making it unnecessary to melt deeply into the base metal. Further, the increased carbon, silicon and manganese in the weld metal materially lower its melting point so that it flows well and is easily placed where desired. All of these factors reduce the strain on the welder and the amount of work that the welding

flame must do, leading to better technical results and, equally important, lower costs.

More recently a further advance has been made, this time in the technique of welding which, coupled with the improved rods, makes modern oxy-acetylene welding a very different procedure from that of the early days. This improved method of oxy-acetylene welding steel is known as the Lindeweld process. It is characterized by the use of: an excess acetylene flame; a special steel welding rod, Oxweld No. 32 C.M.S. Steel Welding Rod; and a special welding technique. It gives welds of superior strength at greatly increased speed and at lower costs.

## ADVANTAGES OF CARBURIZING FLAME TECHNIQUE

By using a carburizing or excess acetylene flame, the welding blowpipe is made to perform an added function over the usual preheating of the base metal and melting of the rod. The procedure depends on the fact that hot steel readily absorbs carbon, that high carbon steel has a much lower melting point than low carbon steel, that carbon very effectively reduces iron oxide, and that carbon disperses or migrates through hot steel at a rapid rate.

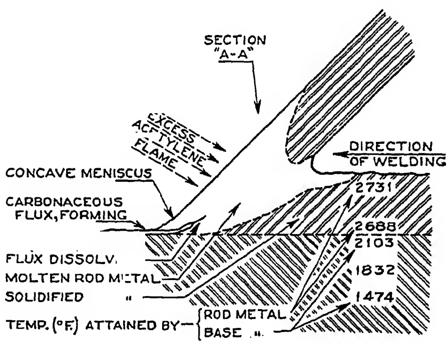


Fig. 68. Sketch indicating metallurgical factors in the Lindeweld process.

Using the carburizing flame for welding and directing the flame backward over the completed weld in such a way that the excess acetylene flame touches the scarf or vee in advance of the welding puddle, serve first to reduce any iron oxide that may be on the surface of the metal. The reduction of the oxide leaves a very porous spongy type of iron which very readily absorbs carbon from the flame and the melting point falls as the carbon increases until with fully carburized iron, it is nearly 700 deg. F. (684 deg. F. to be exact) below the melting point of carbon-free iron.

This simple procedure thus serves to eliminate the trouble making gas-producing scale at a point in advance of the welding operation so that blowholes from this source are prevented, and adds an appreciable amount of strength-giving carbon to the surface of the base metal which, without this treatment, would have been decarburized by its oxide surface. Moreover, the highly carburized low melting point surface of the scarf is easily brought to a sweating condition in advance of the welding operation without any particular attention being paid to it by the operator. This condition is perfect for forming the union between the liquid metal from the rod and the base metal. There is no need for melting into the scarf to insure the presence of clean metal for this union, and the operator's attention is directed mainly to the operation of melting the rod. As a result, the width of the vee need not be as great as in earlier methods. hence less rod must be melted to fill it and this, together with the elimination of melting the scarf, leads to rapid easy welding at a reduced cost for welding materials. The highly carburized surface of the scarf is rapidly absorbed by the added metal and the carbon diffused uniformly through the weld while still at a high temperature giving a uniformly strong and ductile weld metal.

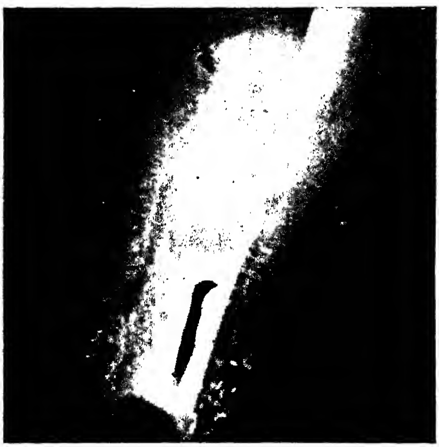


Fig. 69. The Lindeweld process in action. The excess acetylene flame coming from the blowpipe tip (bottom of illustration) melts the welding rod (top of illustration) and conditions the metal surface.

Although the Lindeweld process has found its greatest field of application in the construction of overland pipe lines, its advantages are equally effective in welding steel plate and in welding industrial and building piping.

The technique of the Lindeweld process for welding steel plate is given in Chapter 15; for pipe in Chapter 16.

CHAPTER 15

# Welding Steel Plate

NATURE *of Steel Plate.* The term "steel plate" covers steel more than ⅛ in. thick. For best results selected plate for welding should have a low carbon content, less than 0.30 per cent. Steel used for structural shapes, boiler plate, flange steel, pipe steel, and the grade commonly referred to as mild steel, all come within this classification. Most "tank" steel is low carbon, but this grade should be watched since sometimes material rather high in carbon and fairly low in quality, is sold as tank steel. The steel should also work well and quietly (without sparking) under the blowpipe flame. This, of course, can be determined only by actual welding tests with a piece taken from each lot of steel.

*Welding Methods.* Steel plate can be fusion welded either by the neutral flame forehand technique or by the Lindeweld process which employs backhand technique. The advantages of the Lindeweld process have been pointed out in Chapter 14, page 113. Steel plate can also be bronze-welded according to the general procedure given in Chapter 18.

## NEUTRAL FLAME FOREHAND TECHNIQUE

*Preparation for Welding.* For welding steel plate with the neutral flame technique, the edges of the plate should preferably be beveled 45 deg. so as to form a 90-deg. vee.

*Welding Rod.* For average work, a low carbon steel rod such as Oxweld No. 7 Drawn Iron Rod may be used. For all work where special strength is required, it is recommended that welds be made with Oxweld No. 1 High Test Patented Rod, as much better results can be secured. This rod differs from flux-coated or flux-filled rods in that the elements that supply the fluxing action are a part of the rod itself, providing a cleansing agent throughout the weld metal in such a way that, wherever oxide may be present, active deoxidizers are immediately available to remove impurities in the form of

a floating slag. Due to this fluxing and deoxidizing action of the rod, fusion at the very bottom of the vee is easily obtained. This is one of the important reasons for the superior strength of welds made with this welding rod.

*Flame Adjustment.* For this technique, a neutral flame should always be used.

## PRACTICE WELDS ON STEEL PLATE

*Plate.* Obtain several pieces of steel plate ⅜ in. thick and about 6 in. square. One edge of each plate should be beveled to 45 deg. Support the two pieces of plate on the welding table by means of firebrick with the beveled edges touching.

*Blowpipe Technique.* Use the proper size welding head or tip and working pressures as recommended by the blowpipe manufacturer for ⅜-in. steel. Put on goggles. Light the blowpipe and adjust the flame to neutral.

Melt one end of the vee, holding the blowpipe with the head inclined at an angle of about 60 deg. to the plane of the weld. This is the average welding position. If the head were tilted further the molten metal might be blown ahead of the welding zone; if it were more vertical, the preheating effect of the outer flame would not be thoroughly applied and there would be more danger of melting and blowing a hole through the bottom of the weld. The tip of the inner cone should not quite touch the molten metal.

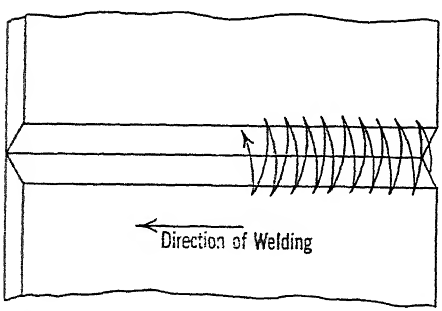



Fig. 70. Swinging motion of blowpipe.

In plate of this thickness, it is clear that the metal from both sides of the vee cannot be thoroughly fused unless the blowpipe is moved from side to side across the vee. For this reason it is necessary to develop a swinging motion when welding steel plate with this technique. When the end of the vee has begun to melt, move the blowpipe from one side of the vee to the other and back again, making sure that the metal on

each side is thoroughly fused. At the same time the blowpipe must work forward along the line of weld.

If difficulty is experienced in acquiring the necessary swing it may be advisable to complete this first weld at the bottom of the vee without attempting to add any welding rod. Merely move the blowpipe gradually along the line of weld, as fast as

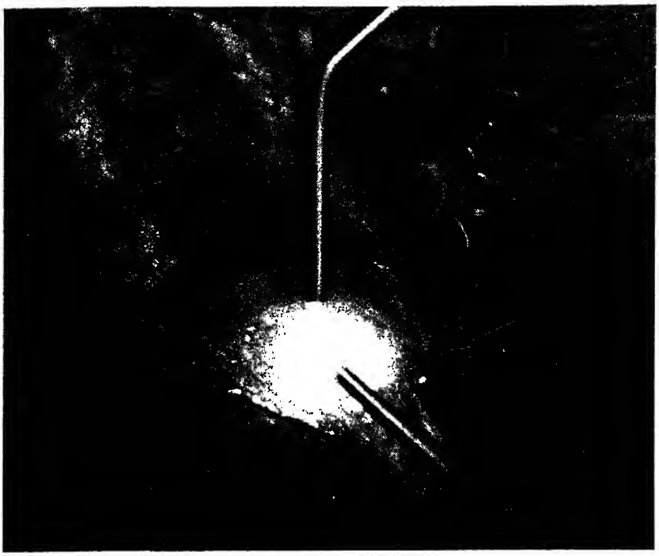


Fig. 71. Position of welding rod and blowpipe in neutral flame forehand technique.

the metal becomes well melted, at the same time swinging the flame from side to side as indicated in Fig. 70.

*Use of Welding Rod.* When the blowpipe motion has been mastered, set up two more pieces of plate in the same way and repeat the experiment, using welding rod. The weld is started just as before; that is, a small spot at one end of the vee is thoroughly melted, forming a small puddle of molten metal. While this puddle is being formed, the tip of the welding rod is brought into the outer envelope flame of the blowpipe. In this way the end of the rod is heated; by the time the puddle of molten steel has been formed at the bottom of the vee, the welding rod should be almost to the melting point. Before it

actually begins to melt, however, the tip of the rod should be dipped below the surface of the molten puddle. Steel welding rod should always be added in this way. Never hold the tip of the rod above the surface of the molten puddle and allow it to melt drop by drop into the puddle. The reason for this is, of course, that rod melted under the surface of the puddle is completely protected from oxidation. The positions of welding rod and blowpipe for this neutral flame forehand technique are shown in Fig. 71.

As the rod melts it should be moved from side to side in the puddle, the motion being just opposite to that of the blowpipe. At first it will be found quite difficult to co-ordinate the motions of each hand. If attention is diverted from the rod to the blowpipe, the tip of the rod may be moved out of the molten puddle. When this happens, the rod instantly sticks to the cooler metal on the sides of the vee and it will have to be melted off with the blowpipe flame before welding can proceed. The beginner will probably find this very annoying, but before long he will be able to control the motion of the rod so the tip is always free and in the molten puddle.

*Changing Rod.* According to the individual preference of the welder, the rod may be held straight or, as is more common, bent as shown in Fig. 75. Hold the rod in the blowpipe flame until red hot and then bend it at the hot spot by pushing the end against the top of the welding table. When a length of welding rod has been used down to the point where it becomes uncomfortable to hold, a new length can be quickly welded on. Take the flame away from the weld while the tip of the rod is still under the molten puddle. The puddle metal will cool rapidly, holding the rod in position. Take a new length of welding rod and, holding it in contact with the old piece, weld the ends together in the blowpipe flame. This takes only a few seconds and has the advantage of using up rod completely.

*Reinforcement.* As the weld proceeds, the rod should be added until the surface of the joint is built up a little above the edge of the plates. This reinforcement is customary in all welding on steel plate. The small amount of oxide that forms during welding remains on the surface as a scale, and

can be easily removed when cold. Any impurities that may have existed in the original steel also tend to work to the surface during the welding. In the completed joint they will consequently be located in the reinforcing portion. This can be removed, if desired, by grinding or machining, leaving metal of highest quality and of uniform thickness with the rest of the plate.

Welding is continued by a gradually advancing puddle of molten metal, until the end of the vee is reached. At this point, in order to finish the work properly, it will be necessary to prevent the molten metal from running over the edge. As the end is approached, raise the blowpipe flame slightly. In this way it will be found possible to chill the molten metal slightly so it will not run like water.

## TESTING THE WELD

When the weld has been completed, take the cutting blowpipe and cut parallel strips about 2 in. wide across the plate so the joint will be in the center of the strips. Clamp one of these strips in a vise with the weld flush with the jaws. Using a small hammer, bend the top of the piece in the direction away from the bottom of the weld; that is, the piece should be bent so the bottom of the weld is stretched. (If more convenient, clamp the strip to an anvil.)

Do not call yourself a good workman until you can bend these pieces 90 deg. without any evidence of cracking. Indeed, a first class weld in steel plate can be bent through 180 deg. without failure.

*Nature of Defects.* On these first attempts the student will probably find evidence of weakness before the piece has been bent very far. Remove it from the vise and examine it carefully. Cracks are usual indications that thorough penetration or fusion has not been secured. Adhesions show up where weld metal splits away from the unmelted sides of the bevel. Overheated metal is coarsely crystalline. Burnt metal and oxide inclusions show up by peacock tints in the broken surface.

By careful study of these test pieces it is possible to judge the faults and take steps to correct them in subsequent work.

Practice with test pieces until the bending test shows sound, strong welds.

*Tension Tests.* If the welder is working in a shop having facilities for making tension strength tests, it will of course be desirable to have test coupons frequently cut from his specimen welds. The results obtained in the tensile testing machine will give an even better indication of the quality of the work. A good single vee weld, ground flush on both sides, should have a strength of 45,000 lb. per sq. in. if made with low carbon welding rod, or 55,000 lb. per sq. in. if made with High Test welding rod. A good test piece, made with double vee weld, ground flush, should develop at least 50,000 lb. per sq. in. if welded with low carbon iron, or 60,000 lb. per sq. in. if made with High Test rod. The latter strengths are so high that the plate itself will break unless the highest quality firebox or flange steel is used.

Fig. 72. Observe spacing of this longitudinal tank seam.

## LONG SEAMS

In setting up long seams for welding in plate, the edges should not be parallel but should diverge approximately ¼ in. for each foot in length. This spread will draw together as welding progresses. See Fig. 72.

The actual amount of spread required depends to a considerable extent upon the length of seam and the speed of welding, so the allowance of ¼ in. per ft. should be varied as experience indicates.

Plates may be held in position for welding, either by the use of clamps or by making tack-welds (short welds, not more than 1 in. in length) at intervals along the seam. During neutral flame welding, tack-welds should be melted out and re-welded.

## WELDING HEAVY STEEL PLATE

*Single Vee.* On steel plate ½ in. or more in thickness, it is necessary to modify the welding technique somewhat to obtain best results for single vee welds.

Take two pieces of ½ in. plate about 6 in. wide and 12 in. long and bevel the 12 in. sides to 45 deg. as before. Consult the blowpipe manufacturer's table and change the tip size and gas pressures as indicated for ½ in. plate. Place the plates on the welding table with the beveled edges together at one end and spaced about 1/16 in. at the other.

*Welding in Layers.* The weld is built up in layers, a section at a time.

First fuse the bottom and sides of the vee thoroughly to form a puddle that will about half fill the vee. Be particularly careful to get thorough penetration and fusion in making the bottom layer. Carry this layer forward for about 1 in.

The second step is to complete this section of the weld by building up a second layer on top of the first. This upper layer must be thoroughly fused with the lower one as well as with the sides of the vee. The upper layer should be built up about 1/16 in. above the plate surface.

Carry the weld down over the forward end of the first layer and continue it along the lower half of the vee for about 1 in. Continue the weld as a series of overlapping layers. Each of these layers must be carefully fused with the preceding layer.

The reason for making this weld in layers is that it is very difficult to control a molten puddle of the size required to make the weld in a single layer. For the beginner it is out of the question and even after ability to control deep puddles has been developed by practice, it is advisable to weld heavy plate in layers whenever a weld of highest quality is desired.

*Testing.* The joint in this ½ in. plate should be tested according to the method outlined for the ⅜ in. plate above.

*Double Vee.* Where the design permits, plate thicker than ½ in. should be beveled from both sides so as to form a double vee for welding. (See Fig. 43, page 80.)

Take two pieces of ¾ in. steel plate and bevel the edges from both sides. Place in a position for welding and weld the

uppermost vee according to the procedure outlined for ½ in. plate. Then turn the plate over; clean out any drip or oxide carefully from the bottom of the vee with a cold chisel, and weld the vee on the opposite side. In making this second vee the welder should be particularly careful to secure thorough fusion at the bottom of the vee between the first and second welds.

## VERTICAL WELDING

Welding is nearly always done in a horizontal position, but it frequently happens that conditions make it necessary to weld along a vertical seam, or even overhead. As either position requires more skill in handling the blowpipe, the welder should practice by taking two beveled pieces of ⅜ in. plate and supporting them in an upright position by means of firebrick so the beveled edges will form a vertical vee.

Begin welding at the bottom. If the plates are supported on a piece of carbon block it will be easier to control the metal in starting a weld. The blowpipe flame should be held horizontally. The welding rod is held in the vee just above the blowpipe and as the flame is moved from side to side the rod is melted in the puddle that is formed.

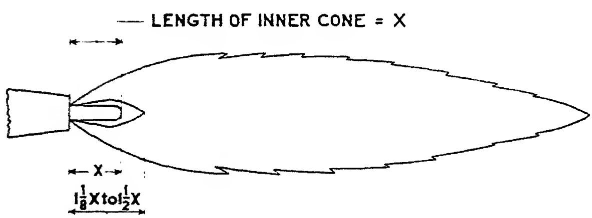



Fig. 73. Diagram showing the adjustment of the excess acetylene flame.

The molten metal is controlled entirely by manipulation of the blowpipe. If the blowpipe is held too long in one position the metal will, of course, become too liquid and run out of the weld. This may be prevented by withdrawing the blowpipe flame slightly whenever there is any evidence of the metal becoming too fluid. Therefore, in addition to the swing of the blowpipe, the student making vertical welds must also learn

how to vary the distance of the flame from the metal in order to control the molten puddle.

As vertical and overhead welding are frequently necessary in welding pipe, the factors which permit control of weld metal in these welding positions are discussed more fully in Chapter 16, page 126.

LINDEWELD PROCESS FOR STEEL PLATE

*Preparation for Welding.* For welding by the Lindeweld process, the edges of the plate should preferably be beveled 35 deg. so as to form a 70-deg. vee.

*Welding Rod.* Oxweld No. 32 C.M.S. Steel Welding Rod should always be used for the Lindeweld process.

*Flame Adjustment.* As explained on page 113, welding by the Lindeweld process is done with an excess acetylene flame. The length of the excess acetylene "feather" in the flame as measured from the blowpipe tip should be from 1⅛ to 1½ times the length of the inner cone, also measured from the blowpipe tip, as in Fig. 73.

*Technique.* Support two 6-in. square pieces of ⅜-in. steel plate beveled for a 70-deg. vee on the welding table by means of firebrick with the beveled edges almost touching.

Welding by the Lindeweld process is done with backhand technique. The blowpipe is held so that the flame points in a direction opposite to the direction of welding. This means that as welding progresses the flame points backward over the completed portion of the weld.

The manipulation of the rod and flame is comparatively simple. First apply the inner cone of the flame at the bottom of the vee until the surfaces sweat or melt slightly. Then raise the inner cone and bring it back to bear more on the end of the welding rod and upper portion of the vee; then bring it slightly forward and lower it again to prepare the bottom of the vee for the advancing puddle, and so on. Hold the tip of the inner cone quite close to but never actually touching the vee, puddle or welding rod.

Securing fusion at the root of the weld will be relatively simple if heat control is proper. Hold the inner cone sufficiently close to the bottom of the vee at the end of the forward movement of the flame so that the puddle will flow down and

ahead after the two bottom edges are ready for fusion, bridging over the space of from 1/16 in. to 3/32 in. that may be present between the plate edges. Unless too much heat is applied at this point, bridging will always occur, thoroughly fusing together the bottom of the vee with little or no protrusion or bead of weld metal inside the joint. If the spacing is enough greater than 3/32 in. to make bridging difficult, add weld metal from the end of the welding rod since such metal will be more plastic and less likely to fall through. Do not move the rod ahead, however, until the lower sides of the vee have been properly prepared by the flame.

The motion given the end of the welding rod should be a moderate push and pull movement in the line of the joint and well within the boundary of the puddle. The relative motions of the rod and flame are alternately toward and away from each other. Avoid excessive flame or rod manipulation and do not ripple the metal with the blowpipe or puddle it with the rod. Add molten metal from the rod to the base metal simply by fusion with the surface and avoid subsequent overheating or puddling.

Maintain the puddle as small as practical, keeping the weld only slightly wider than the top of the vee, and with sufficient reinforcement so that there will be no valleys at the edges or center of the weld. Where the sides of the vee are comparatively clean and smooth, the excess acetylene flame will cause the metal just ahead of the puddle to sweat and run slightly, enabling the puddle to flow ahead smoothly and without forcing. If the surfaces of the vee are rough or uneven, or covered with either rust or scale, melt them just enough to expose clean base metal to the extent of about 1/4 in. immediately ahead of the advancing puddle. Never allow the puddle to surge and cover over surface oxides ahead of the sweating or melting areas as this would cause defects in the weld.

In welding long seams, heavy plate and vertical joints by the Lindeweld process the general principles outlined on pages 120 to 122 apply with, of course, such modifications as are made necessary by the difference in technique, angle of bevel, etc.

CHAPTER 16

# Welding Steel Pipe

SCOPE *of Subject.* Pipe has a great many industrial applications. Steel pipe in particular is used for lines carrying water, oil and gas over long distances and for carrying steam, water, compressed air and various other materials in industrial plants, as well as in public buildings and residences. Pipe new and old is also formed into a large variety of plant equipment. Petroleum refineries have been particularly active in the manufacture of special equipment from pipe.

The construction of overland pipe lines and the installation of oxy-acetylene welded piping systems are subjects of such magnitude that a full discussion is not possible here. This chapter will present certain fundamentals and will describe the various standard methods of welding line joints (see page 81).

In addition to being used for joining two straight lengths of pipe, line joints are also used in installing certain types of welding fittings, such as elbows, tees, reducers, caps, etc., which are manufactured especially for use in welded pipe construction.

The fabrication of welded fittings by cutting and welding involves a knowledge of templets and their use to insure correct cutting. It also involves other types of joint design, some of which have been indicated on page 82.

For a comprehensive treatment of the whole subject of oxy-acetylene welded piping, reference should be made to the two books, "Design of Welded Piping," and "Fabrication of Welded Piping." * Those who intend to specialize in pipe welding or who may work on welded pipe lines or piping installations will find these books invaluable.

*Rolling and Position Joints.* In actual work on pipe of any size, two general types of joint are made. The first of these

* Published by The Linde Air Products Company.

is known as the rolling joint because it is used wherever the pipe can be turned as it is welded. This allows the work to be done constantly in the most convenient position.

Wherever this is not possible the weld must be made in a fixed position. In pipe line work such a weld is referred to as a position joint, tie-in weld, or bell-hole weld. (When such a weld is made at the bottom of a trench it is necessary to dig a hole called a bell-hole just under the joint so there will be room to work.)

All operators should be familiar with the technique of these two types of pipe welds.

## PIPE WELDING METHODS

As in welding steel plate, Chapter 15, there are two general techniques used in welding pipe—neutral flame forehand technique and the Lindeweld process.

Because of its many advantages, see p. 113, the Lindeweld process is particularly recommended for all pipe welding. This improved method of welding was developed especially for use in pipe line construction, and it has already been used on over 10,000 miles of high pressure oil and gas pipe lines ranging in diameter from 4 in. to 26 in., and hundreds of thousands of feet of industrial and building piping.

As pipe welding in general and position welds in particular involve welding in all positions, flat, vertical, overhead and horizontal, a thorough knowledge of the factors which permit control of the weld metal in these various positions is essential.

Due to the effect of gravity, the molten weld metal in the puddle always tends to seek a lower level. This tendency is restrained by the following forces: (a) cohesiveness of the puddle, (b) support provided by the base metal and solidified weld metal, (c) pressure of the flame or burning gases against the end of the puddle, and (d) the manipulation of the welding rod in the molten metal. The action of gravity on liquids requires no explanation, but an understanding of the forces maintaining the molten or liquid metal in the form of a puddle is necessary if the basic principles of welding technique are to be mastered.

The most important force counteracting the effect of gravity is the cohesiveness of the molten metal which determines the

quantity of molten metal that will adhere or stick to base metal and welding rod without running or falling. One factor affecting cohesiveness is the amount of heat applied. More heat than necessary increases the fluidity of the molten metal, bringing about a greater tendency of the puddle to run or fall. Another factor is the composition of the molten metal, which is principally rod metal, but contains, to a greater or less extent, some base metal. Certain welding rods, such as Oxweld No. 32 C.M.S. Steel Welding Rod, contain alloying elements which increase the viscosity or decrease the fluidity of the molten metal, thereby enabling a larger puddle of metal to be carried which is especially valuable in vertical and overhead welding.

Welding directly overhead, it is possible to maintain a surprisingly large puddle of molten metal if just one precaution is observed. Water or oil sprayed lightly on the under side of a flat surface will fall only after a complete drop has taken shape. Thus, if the welding puddle is kept from forming into a drop, cohesion prevents its fall.

When welding vertically, as when bringing a puddle up the side of a pipe joint, the influence of cohesion in maintaining the puddle decreases. This is because the same amount of liquid that could be suspended on the underside of a flat surface will collect and run on a vertical surface. Consequently the pressure exerted by the burning gases must be relied upon to a considerable extent in maintaining a puddle of fair size. The solidified weld metal just below the puddle acts as a ledge and supplies additional support.

As the welding nears the top of the pipe, the solidified weld metal and the vee of the joint provide more and more support for the puddle while the effect of the flame pressure and cohesiveness in maintaining the puddle becomes greatly reduced. It is at a point near the top that the largest and most fluid puddle can be carried.

If the puddle is started at the top, however, and carried to the bottom of the joint—the reverse of the preceding method—different conditions exist. At the beginning, the vee provides considerable support for the puddle as before but as the side of the joint is approached, the pressure of the flame must be relied upon more and more to keep the molten metal in place.

In this case, where there is no supporting ledge of solidified weld metal to provide partial support, the puddle carried must be relatively shallow to correspond to the holding ability of cohesiveness and flame pressure. To aid in keeping the puddle shallow, manipulation of the welding rod is employed. The end of the welding rod, constantly melting, is used to distribute the molten metal throughout the puddle by a slow but constant movement—circular, elliptical or in a straight line—so the metal will not collect at one spot and run or fall due to the action of gravity. By this means, the molten metal is "placed" near the rear edge of the puddle for the short interval required to cool it to a plastic state from which it solidifies quickly to form deposited weld metal as the inner cone of the flame is moved further away. In this manner, weld metal can be deposited rapidly and accurately as to weld cross-section in any position of welding.

When the bottom of the joint is reached, the same condition exists as before for overhead welding. The puddle is kept from forming into a drop by means of flame pressure and the welding rod, while cohesion holds it in place. For other positions of welding and other types of joints, the same principles of puddle control apply.

## Neutral Flame Pipe Welding

*Joint Design.* The recommended design for line joints for neutral flame welding of pipe with wall thickness 3/16 in. or over is the standard open single vee butt weld with 45 deg. bevel, Fig. 42, page 80.

*Beveling.* The pipe ends should be beveled 45 deg. with a 1/16 in. unbeveled shoulder at the inner wall of the pipe.

*Spacing.* Before tack-welding, the ends of the pipe should be lined up and spaced as follows for standard weight pipe:

| Nominal diameter, in. | 2 | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|
| Spacing, in. | 3/32 | 1/8 | 1/8 | 1/8 | 3/16 | 3/16 | 3/16 | 1/4 | 1/4 | 1/4 |

*Tack-Welding.* Pipe should be tack-welded in three places at least for the smaller sizes and at four points for 10-in. and

12-in. pipe. For larger sizes, tack-welds should be at intervals not more than 10 in. apart. The tack-welds should be about 1 in. in length, without reinforcement.

*Welding Rod.* For all neutral flame pipe welding, Oxweld No. 1 High Test Patented Steel Welding Rod is recommended.

*Flame Adjustment.* The flame should always be adjusted to neutral.

## ROLLING WELD

*Preparation for Welding.* Two short lengths of 4-in. or 6-in. steel pipe with ends beveled 45 deg. should be spaced and tack-welded as recommended above. Support the pipe so that it can be turned easily during welding, see Fig. 75.

*Welding Technique.* Using the standard neutral flame forehand technique as described for steel plate, page 116, start the weld in the upper quadrant of the pipe at a point about 70 deg. down from the top center line of the pipe, that is, about 20 deg. above the quarter point.

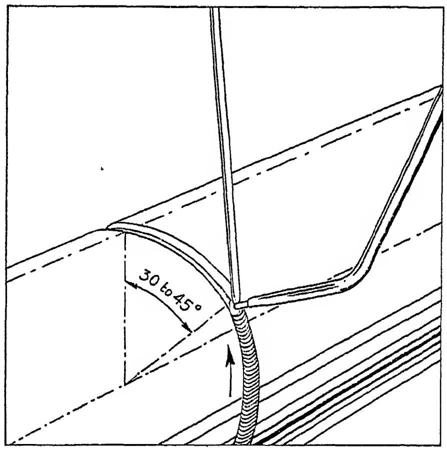



Fig. 74. Position of rod and flame for making rolling welds with forehand technique.

Point the blowpipe tip upward so that the direction of the flame is nearly tangent to the circumference of the pipe. Carry the weld upward until it reaches a point about 20 deg. below the top center line.

Then turn the pipe until this point is about 70 deg. down from the top. Continue welding and turning in this way until the joint is completed.

Whenever a tack-weld is encountered, re-melt and re-weld it to insure a sound, continuous weld. Similarly, in completing the weld, re-melt and re-weld the first part of the weld for a distance equal to at least twice the thickness of the pipe wall.

Then continue for about 3 in., heating the completed weld to a full red. This eliminates internal strains which accumulate where the welds overlap.

*Testing Practice Weld.* When the weld has cooled, the pipe should be cut into strips lengthwise. Inspect the inside of the joint for complete and uniform penetration, without the presence of objectionable "icicles" protruding inside the pipe. The strips should be clamped in a vise and bent by hammering until a break is obtained through the weld. Break some by bending forward, and some by bending backward. Visual examination will then show whether or not penetration has been thorough and the weld metal sound and tough.

Fig. 75. A convenient arrangement for making practice welds in steel pipe.

*Advanced Technique.* As experience is gained in the control of the puddle on the side of the pipe, start the weld lower down until you are able to start it at the quarter point, 90 deg. down from the top. This will decrease the number of partial turns necessary. Do not carry the weld up beyond the 20 deg. point, however.

*Pipe Turned by Helper.* Where the pipe is turned by a helper, as in pipe line practice, neutral flame welding should preferably be done continuously in the upper quadrant in a zone from 45 to 30 deg. down from the top of the pipe, Fig. 74.

## POSITION WELD

With forehand technique, a position weld is started at the bottom of the pipe and carried up one side of the pipe to the top; then restarted at the bottom and carried up the other side to complete the weld. As this involves vertical and overhead welding it is advisable to practice puddle control before start-

ing to make an actual weld. Review the factors governing puddle control, page 126.

*Manipulation of Blowpipe.* Support a short piece of 4-in. or 6-in. steel pipe in such a way that the blowpipe can be conveniently manipulated both at the bottom and the top of the pipe. Chalk a line around the pipe.

Using the blowpipe alone, without rod, start at a point on the chalk line at the bottom of the pipe. With the blowpipe held so that the flame points directly upward at this spot, melt a small puddle and carry it up the side of the pipe following the chalk line until the top is reached. Considerable practice will be required before this can be done properly.

*Manipulation of Blowpipe and Rod.* When a satisfactory degree of proficiency is reached, repeat the experiment using welding rod. Follow the chalk line and build up a ring of weld metal on the surface of the pipe.

Fig. 76. Typical installation of oxy-acetylene welded piping.

*Welding Technique.* Once the fundamental principles of puddle control have been mastered in this way, the welding of an actual joint is relatively simple.

Support in the same way two short pieces of pipe beveled, spaced and tack-welded as before.

Start the weld at the bottom and carry it up the side until the top is reached. Then restart at the bottom and carry the weld up the other side until finished. Observe the same precautions noted on page 129 in rewelding tack-welds and in finishing. Test the practice welds as described on page 130.

# Lindeweld Process for Steel Pipe

*Joint Design.* The recommended design for line joints for welding of pipe with wall thickness of 3⁄16 in. or over by the Lindeweld process is the standard open single vee butt weld with 35 deg. bevel, Fig. 77.

*Beveling.* The pipe ends should be beveled 35 deg. with a 1⁄16-in. unbeveled shoulder at the inner wall of the pipe.

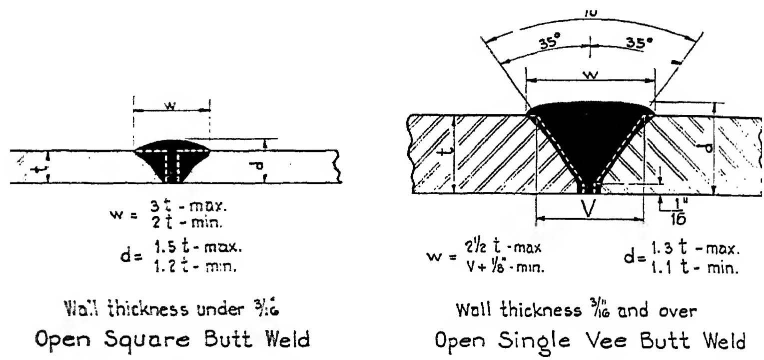



Fig. 77. Pipe joint design for welding by the Lindeweld process.

*Spacing.* Before tack-welding, the ends of the pipe should be lined up and spaced as follows for standard weight pipe:

| Nominal diameter, in. | 2 | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 20 and over |
|---|---|---|---|---|---|---|---|---|---|---|
| Spacing, in. | 3⁄32 | 3⁄32 | 1⁄8 | 1⁄8 | 5⁄32 | 5⁄32 | 5⁄32 | 3⁄16 | 3⁄16 | 3⁄16 |

*Tack-Welding.* Under the best conditions for welding, two tack-welds will be sufficient for the smaller sizes, three for pipe 6 in. to 14 in. in diameter, and four for diameters larger. Tack-welds should be small, about three times the pipe wall thickness in length and two-thirds the pipe wall in thickness at the middle. Each half of the tack-weld should slope from the middle to the bottom of the vee, so that the welding puddle can be readily carried over. Tack-welds become a part of the final welded joint, so it is important that they be carefully made.

*Welding Rod.* Oxweld No. 32 C.M.S. Steel Welding Rod should always be used for the Lindeweld process.

*Flame Adjustment.* The flame should be adjusted so as to have an excess of acetylene. As indicated in Fig. 73, the total length of the excess acetylene cone should be from 1⅛ to 1½ times the length of the inner cone.

## ROLLING WELD BY THE LINDEWELD PROCESS

*Preparation for Welding.* Two short lengths of 4-in. or 6-in. steel pipe with ends beveled 35 deg. should be spaced and tack-welded as recommended. Support the pipe so that it can be turned easily during welding.

*Welding Technique.* Using the standard technique for the Lindeweld process, page 123, start the weld at the top of the pipe between two tack-welds. Start the weld with a taper of about 30 deg. as this will make it easier to finish the weld. Carry the weld down the side until it reaches a point about 70 deg. below the top center line of the pipe.

Then turn the pipe until this point is at the top, Fig. 78, and continue the weld down the side. Repeat this sequence of welding and turning until the point is completed.

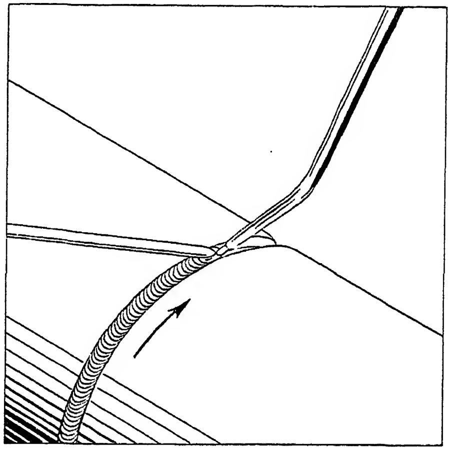


Fig. 78. Position of rod and flame for making rolling weld by the Lindeweld process.

In carrying the weld over tack-welds it is unnecessary to melt them out, since, when properly made, they can be considered a part of the welded joint. It is merely necessary to secure proper fusion to the surface, as is secured to the side walls of the vee.

If the weld is stopped for any reason, the welder upon restarting should reheat to a dull red for an overlapping distance of one or more inches, so the face of the weld at the starting point can be brought uniformly to the melting temperature necessary for proper fusion.

To finish a weld, a similar procedure should be followed. Welding should be discontinued approximately ¼ in. from the finish and the face of the weld at the original starting point then brought to a melting temperature, first heating to a dull red for one or more inches back. The flame should then be directed to the metal at the point where the welding was stopped, and the puddle restarted and carried ahead, just as though going over a tack-weld. The puddle should be reduced in size as the full thickness of the weld at the starting point is reached, so that it will finally disappear as the flame is drawn gradually ahead.

*Testing Practice Weld.* The practice weld should be examined as described on page 130.

*Pipe Turned by Helper.* Where the pipe is turned by a helper, Lindewelding should preferably be done continuously in the zone from the top center line of the pipe to a point 20 deg. away.

POSITION WELD BY THE LINDEWELD PROCESS

With backhand technique, a position weld with the pipe horizontal is made by starting at the top of the joint and

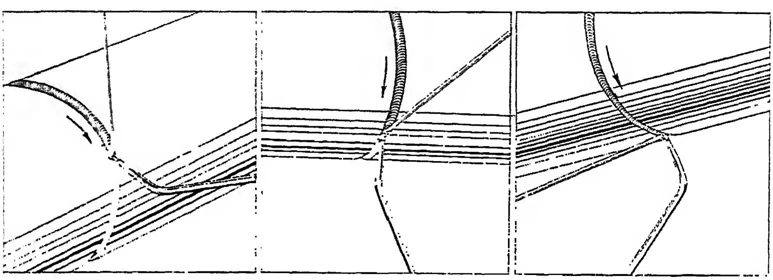


Fig. 79. Making a position weld by the Lindeweld process.

carrying the puddle to the bottom, then restarting at the top and completing the opposite side. As this involves vertical and overhead it is advisable to practice puddle control as recommended on page 126. Chalk lines on the surface of the pipe and practice carrying a puddle from top to bottom, first with the blowpipe alone, then with blowpipe and rod.

*Welding Technique.* When the fundamental principles of puddle control have been grasped, make a practice weld.

Support in a suitable position two short pieces of 4-in. or 6-in. steel pipe beveled, spaced and tack-welded for welding as before.

The Lindeweld process for position welding differs from that for rotation welding principally in that a smaller puddle is carried and increased manipulation of the end of the welding rod is required.

Start the puddle at the top of the joint and carry it for a short distance just as in rotation welding. As the slope of the joint increases, the puddle would tend to run ahead faster than the base metal could be prepared for it, if rotation welding technique were still maintained. To control the puddle and build up sufficient reinforcement, keep a smaller puddle and spread it out thinly with the end of the welding rod to keep it in place. To do this, give the end of the rod an elliptical to circular motion, depending on the length of puddle carried. As the welding progresses down the side of the pipe, change the angle of the tip gradually until in the overhead position, the flame is pointed almost vertically into the vee. As in rotation welding, take care that the surfaces of the vee preceding the puddle are sweating or melting slightly before weld metal is allowed to advance. Study Fig. 79.

CHAPTER 17

# Welding Cast Steel

CHARACTERISTICS *of Cast Steel.* Steel castings are frequently used where high strength and shock resistance are essential. Cast steel can be distinguished from cast iron by its superior toughness; by the fact that a cold chisel will cut a ductile chip; by the much finer grain structure; by its steely rather than gray color, and the higher metallic lustre shown on a fresh fractured surface; and also by the behavior of the metal under the blowpipe flame.

*Preparation.* Because of its ductility and toughness, a good steel casting will bend considerably before breaking. Examine all broken steel castings carefully for such distortion. Any heating and bending required to restore a casting to its original shape and alignment should be done before beveling and welding.

Small steel castings require no preparation other than beveling the edges to be welded and making sure the surface is clean. Beveling can be done with the cutting blowpipe or chipping hammer; in some instances by grinding. If the cutting blowpipe is used, be sure that the edges are thoroughly cleaned of oxide and scale by a grinding wheel, or with a wire brush before starting to weld.

*Preheating.* Larger castings with thick walls (or of such design that localized heat of welding might set up strains in the steel) should be preheated to a bright red, after beveling the edges to be welded. Whether preheating should be general or local depends upon the design of the casting.

*Welding Rod.* Since strength is essential in a steel casting, Oxweld No. 1 High Test Patented welding rod is recommended.

*Welding Technique.* Welding the casting, whether preheated or not, is done in a series of overlapping layers according to the method given on page 121 for heavy steel plate. As it is possible the break may have resulted from a sand hole or dirty spot (especially where defective castings are being re-

claimed in the foundry), watch the weld carefully for the bright spots or craters in the molten metal that are evidence of such defects. Melt under these spots with the blowpipe flame and work them to the surface. Sand and slag should be scraped out by the welding rod.

Where the break occurs between sections of unequal thickness, direct the heat of the blowpipe flame toward the heavier

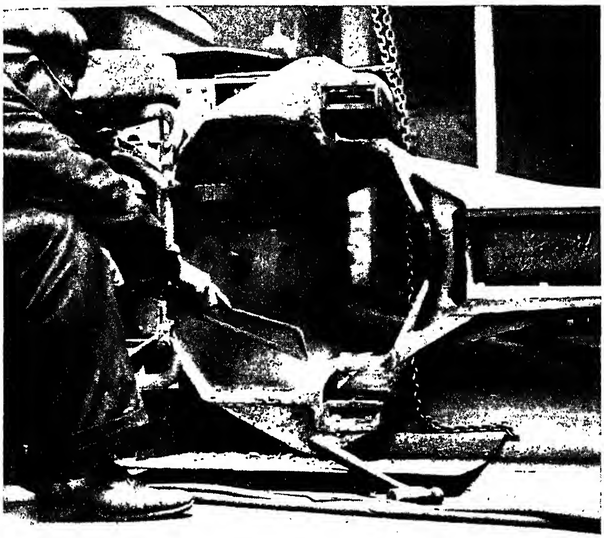


Fig. 80. Welding the cast steel frame of a crane truck.

section, so as not to overheat the lighter. Both sections should become molten as nearly as possible at the same time and, of course, to accomplish this more heat must be supplied to the heavier part.

## EDGE WELDING

Two special problems are met frequently in work on steel castings. These are: (1) building-up lugs, bosses, teeth on gears, or misrun edges, and (2) filling holes. The technique for either is slightly different from the ordinary run of work on cast steel.

Building-up edges and lugs affords excellent practice in the

control of weld metal. As experience is gained the operator can, by carefully working welding rod and blowpipe, add metal very close to the finished shape.

In building-up a lug, be careful to get thorough fusion of weld metal with base metal as the first layer is applied. Then as a molten pool is formed, add welding rod in the pool. Control the molten metal at the edge by drawing the blowpipe back a bit if the metal appears to become too "runny." You will soon learn to flip the flame away quickly, or direct the flame in such a way that the weld metal is readily controlled.

Be sure that no molten metal is run over the sides down the relatively cool surface of the already solidified metal. No weld is formed on such cold metal. It "adheres" only. Metal adhering like this will break off when the lug or tooth takes a load.

When working at the edge, the metal can be more easily controlled if the blowpipe flame is held slanting upwards and inwards toward the center of the lug. Build up just a little more than the finished dimensions so the part can be dressed to a smooth surface.

## FILLING HOLES

In welding up a hole that extends clear through a piece of steel, it is best to countersink the hole first or to fuse down the sides of the hole so as to get the same result as a countersink. Then start welding at the bottom edge and add weld metal all around in progressively narrowing circles until the hole is closed at the bottom. Continue to add metal a layer at a time until the hole is filled. Fuse each layer thoroughly to the one below and to the sides of the hole.

Where the hole extends through a thick section, it is advisable to countersink from both sides. Then fit a piece of 1/8-in. steel plate in the hole at the smallest part where the countersinks meet. With this plate acting as a bottom piece, fill up the hole from one side, as just described. Turn the piece over and complete the filling operation from the other side. Be sure to fuse thoroughly the piece of steel plate.

A depression is filled in the same way. Be very sure that the bottom and sides are thoroughly fused before adding weld metal.

When any welding on steel castings in a preheating furnace is finished, cover the casting thoroughly with asbestos paper or other insulating material to retain the heat, and then let the fire die out. Allow the casting to remain covered until cold.

Where castings are not preheated the weld area should also be protected with heat-insulating material, and allowed to come to room temperature gradually. In a steel foundry all reclamation welding should be done after the casting is cleaned but before it is annealed.

CHAPTER 18

# Bronze-Welding

CHARACTERISTICS. Bronze-welding is a method of joining the higher melting point metals such as cast iron, steel, nickel and copper, by the use of a bronze bonding material. For many welding applications bronze-welding offers the advantages of speed, economy and ability to do jobs which otherwise might be difficult or impossible.

Fundamentally, bronze-welding is an outgrowth of the older process of brazing. The basic theory of the process lies in the fact that molten brass or bronze will flow onto the properly

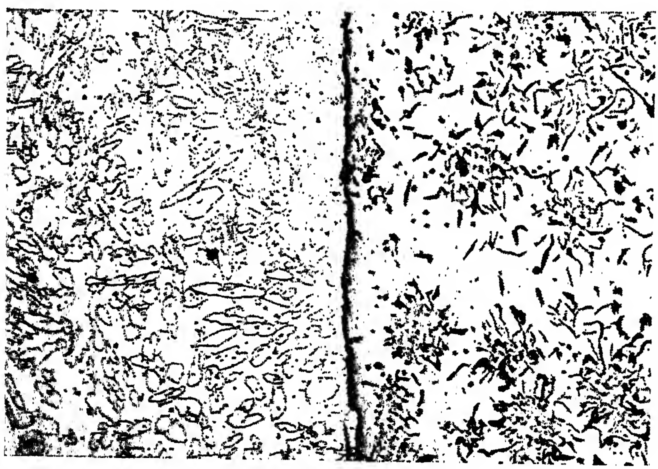


Fig. 81. Photomicrograph of a bronze-welded joint on cast iron. Left—bronze. Right—cast iron. This magnification reveals that there is no intermingling of the two metals.

heated and fluxed surface of higher melting point metals to give a bond or molecular union that has excellent strength.

In bronze-welding, the bronze is supplied in the form of welding rod. The use of bronze in this convenient form, together with the fact that the bronze welding rod is melted by the heat of an oxy-acetylene blowpipe flame, gives the welding

operator complete control of the process at all times. Although the base metal is never actually melted in bronze-welding, the unique characteristics of the bond between the bronze weld metal and the base metal give a joint that is fully comparable to a fusion weld. See Fig. 81.

## ADVANTAGES OF BRONZE-WELDING

Several particularly important advantages result from the fact that bronze-welding requires less heat than fusion welding. The speed of welding is increased which means a decrease in time and gas consumption for a given job. The fact that the base metal is not melted in bronze-welding greatly simplifies the welding of cast iron, as it largely eliminates the extensive preheating required when this metal is fusion welded.

Certain metals, such as malleable iron and heat-treated steels, whose original properties are either destroyed or seriously affected by fusion, can be readily bronze-welded. The coating on galvanized iron is less affected by the lower temperature of bronze-welding, and this same factor is frequently utilized to minimize distortion in sheet metal fabrication.

Bronze-welding also provides a convenient method for joining dissimilar metals such as malleable iron or copper to iron or steel.

Obviously, bronze-welding should not be used where the part is to be heated subsequently, either in service or in heat-treatment, to temperatures higher than the melting point of bronze. It should also be remembered that bronze loses strength rapidly at temperatures above 500 deg. F. There are also certain cases where the difference in color between bronze and the base metal would be undesirable.

Bronze-welding is also widely used in building-up wearing surfaces, particularly on cast iron, steel and manganese bronze. This phase of bronze-welding is of such importance that it is distinguished by a separate term, bronze-surfacing, and is discussed in Chapter 30.

The present chapter covers the general principles of bronze-welding which are essentially the same for all base metals. For a specific metal, reference should also be made to the chapter devoted to that metal.

## PREPARATION FOR WELDING

*Cleaning and Beveling.* For bronze-welding, it is essential that the base metal be clean and free from foreign matter that might interfere with or prevent the capillary flow or "wetting" action of the bronze weld metal. Oil, grease, dirt, oxides or scale must be removed.

If the edges to be joined are ¼-in. or less in thickness, surface chipping or grinding to bright metal will suffice. If over ¼ in. in thickness, the edges should be beveled to give about a 90 deg. included vee. The beveling operation in itself will expose clean metal. Further than this, in all cases the metal for about ½ in. back from the top edges of the bevel should be thoroughly cleaned off.

Even after such cleaning, many metals retain a superficial coating of oxide that would prevent the bronze weld metal from coming into intimate contact with the base metal. Therefore, it is necessary to remove this coating by the use of a suitable flux during welding.

*Alignment.* Suitable means of assuring proper alignment should always be provided in advance of actual welding. Small

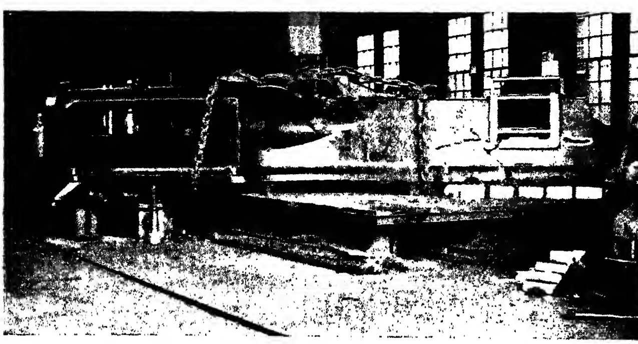


Fig. 82. Fractured hoisting engine bed prepared for bronze-welding. Observe the use of jacks for lining up the parts.

parts can be held in alignment by the use of tack-welds, clamps, or jigs. For large parts, these considerations may involve considerable study and ingenuity. In the repair of multiple fractures in large or complicated castings, careful preliminary

study is advisable to determine the proper sequence of welding operations.

*Preheating.* It is seldom necessary to preheat above a "black" heat for any bronze-welding work. Those who are familiar with fusion welding of castings or large and complicated objects realize that this means a considerable saving. The usual requirement is simply to remove the chill and bring the part to a black heat before starting to bronze-weld.

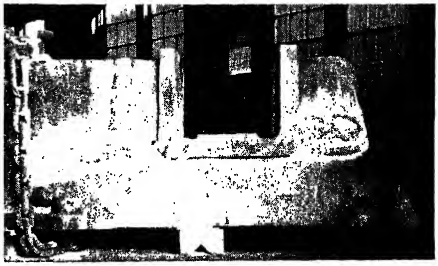


Fig. 83. Part of the completed bronze-weld in the engine bed.

If the casting is small enough to be preheated with the welding blowpipe flame, then a certain amount of local preheating just before welding will do the job very nicely. If the part is larger, it is advisable to use a preheating furnace fired by gas, oil or charcoal. There are other economies that can be obtained through preheating. If the job is apt to be long drawn out, it certainly pays to preheat so that less oxygen and acetylene will be used in bringing the base metal up to the "tinning" temperature.

## WELDING ROD

As joint strength depends directly upon the quality of welding rod used, it is important that the best available rod be used for all bronze-welding.

Until quite recently, bronze welding rods most generally used contained about 59 per cent copper, 40 per cent zinc, and 1 per cent tin. Unreinforced bronze-welds made in steel plate with such rod average about 41,000 lb. per sq. in. tensile strength. Metallurgical research has now developed an all-purpose bronze welding rod containing silicon as an essential alloying element. With this rod, known as Oxweld No. 25M (Patented), bronze-welds with over 55,000 lb. per sq. in. tensile strength and ductility in excess of 30 per cent can be readily and consistently obtained in steel tank plate.

The silicon in this rod functions as a deoxidizer, reducing

oxides of tin, copper and zinc and replacing them with silicon dioxide which floats readily to the surface where it unites with the bronze-welding flux to form a film of slag on the molten metal which greatly retards the formation of zinc fumes. Thus silicon produces a weld metal free from porosity and blowholes and, as a result, one with greatly increased strength and machinability. Due to the soundness and excellent wearing quality of the weld metal, which has an average Brinell hardness of about 96, surfaces built-up from it possess increased resistance to wear.

By slightly increasing the tin content at the expense of the zinc, percentages of other elements remaining about the same, another rod, known as Oxweld No. 31T bronze rod, has been developed. Although it has an average Brinell hardness of about 105, ductility has been sacrificed (elongation being of the order of 5 per cent) which makes 25M better for most joining work where ductility is a factor. Oxweld No. 31T retains its hardness better at elevated temperatures and is therefore excellent for many applications as a bearing bronze.

Oxweld 25M and Oxweld 31T are both remarkably free-flowing because of the carefully balanced content of deoxidizing agents. They melt rapidly, tin easily and solidify quickly, so that in actual application, ease and speed are combined. They lend themselves readily to sectional building-up of large deposits where successive layers are added one after another and are also adaptable for overhead and vertical welding.

## FLUX

The use of flux is essential in bronze-welding to provide the chemically clean surface on the base metal which will insure the intimate molecular union or bond between base metal and bronze weld metal. Oxweld Brazo Flux is recommended. As it is necessary to supply a liberal amount of flux continuously, consideration must be given to the manner in which flux is to be added during the welding operation.

For many bronze-welding applications flux is most conveniently added by dipping the heated end of the welding rod into the can of flux at frequent intervals. Sufficient flux will readily adhere to the heated rod. Where the rate of welding is rapid,

the flux may be made into a thick paste with water and painted on the rod or base metal at the joint. Another method is to heat the rod for a length up to a foot at one end and roll it in flux spread in a long horizontal container.

## BRONZE-WELDING TECHNIQUE

The fundamental technique of bronze-welding and of bronze-surfacing is essentially the same regardless of the composition of the base metal. The general principles are given in the following discussion. Considerations which apply to individual base metals are discussed in the chapter on the particular base metal.

*Flame Adjustment.* For bronze-welding, the blowpipe flame should be adjusted so as to be slightly oxidizing. This is important as it will insure much better bonding between the bronze and the base metal. The proper flame is obtained by first adjusting the flame to neutral and then closing the blowpipe acetylene valve slowly until the inner cone has been reduced in length by about one-tenth. The flame should be checked periodically for this adjustment.

*"Tinning."* The operation of forming the molecular union or bond between the bronze-weld metal and the base metal is the most important step in bronze-welding. The strength of this bond determines the strength of the bronze-welded joint. Because of the importance of this operation, which is known as "tinning", it should receive special study in learning to bronze-weld.

For this purpose provide pieces of cast iron or steel plate with the surface ground so as to expose bright metal.

With the properly adjusted slightly oxidizing blowpipe flame, heat a 2-in. diameter spot on the ground surface of the base metal, moving the flame in a circular manner so as to bring the base metal gradually up to a red heat. When the metal just begins to glow, heat the end of the bronze welding rod in the blowpipe flame and dip the heated end of the rod in Brazo flux so that sufficient flux will adhere to the rod. Then melt the end of the fluxed rod on the heated spot on the metal. If the metal is at the proper temperature for bronze-welding, the molten bronze will flow in a thin layer and spread out over the

heated area. This flow will be like water spreading over a clean, damp surface and will not have the appearance of water on a greasy surface.

If the metal should be too hot, the bronze will tend to boil and to form into drops which roll off as fast as the rod is melted. If the metal is too cold the bronze will not flow properly so as to produce the tinning coating.

Continue to practice this operation until you are able to judge the temperature at which tinning occurs readily. The actual operation of bronze-welding consists essentially in combining into one continuous operation the tinning action and the building-up of the weld to the desired size. It must be remembered that at all times the tinning action must take place just ahead of the main body of weld metal.

For practice in bronze-welding, provide pieces of cast iron or steel plate about 1/4 in. thick with edges beveled by grinding so as to form a 90 deg. vee.

When ready to begin welding, move the blowpipe flame in a circular manner for some distance around the starting point of the weld, expanding the metal slowly and bringing it gradually up to the bronze-welding temperature. Then concentrate the heat on both edges of the vee at the starting point and bring them to the temperature at which tinning takes place. When the tinning action begins, continue adding bronze-weld metal to build up the weld to the desired size. The puddle should be small at first and should be increased in size as it is moved forward until it completely fills the vee and a full size weld is being made. As the weld progresses it is important to make certain that the tinning action takes place constantly just ahead of the puddle.

The inner cone of the slightly oxidizing flame should be kept from 1/8 to 1/4 in. away from the surface of the metal. Usually the flame is pointed ahead of the completed part of the weld at an angle of about 45 deg., with the puddle under and slightly behind the flame. This angle may, of course, vary depending on the position of welding, as in overhead or vertical welding.

Both the rod and flame are given a slight sideways motion in the puddle, characteristic of forehand technique, the motions being opposite to each other.

*Heavy Sections.* On heavy jobs where the thickness of the material is greater than the depth of puddle that can be conveniently carried, it is advisable to make the weld in layers. The weld should progress as a series of overlapping increments. Particular attention should be paid to tinning and to making certain that each increment is thoroughly fused to the previous one.

*Slow Cooling Essential.* When the bronze-weld is completed, it should be allowed to cool slowly to room temperature. The finished job can most conveniently be covered with asbestos paper. This assures slow cooling and protects the part from drafts during the cooling operation. No stress should be placed on a bronze-welded joint until it has completely cooled because bronze has relatively low strength at temperatures above 500 deg. F.

The finished weld should be cleaned with a wire brush to remove any excess flux or slag from the welding operation.

Fig. 84. Building-up a missing gear tooth by bronze-welding.

## BUILDING-UP MISSING SECTIONS

Because of the excellent wear resistance of weld metal produced by modern bronze welding rods, this method is widely used in building-up worn or missing parts. In fact the building-up of worn surfaces by bronze-welding has become so important in recent years that it is now designated by a separate term, bronze-surfacing, and is discussed in more detail in Chapter 30.

*Gear Teeth.* Mechanics who have attempted to replace a broken gear tooth using such makeshifts as stud bolts, will readily appreciate the value of a process which enables the

Fig. 85. Observe how closely the built-up bronze tooth matches the others.

operator to build-up a new tooth so that it is completely and permanently a part of the gear itself.

The operation of building-up a gear tooth affords excellent practice and is something that every operator should learn.

While carbon blocks are sometimes used to assist in controlling the weld metal during the building-up operation, it is better practice to learn how to build-up the tooth without such aid.

To do this the operator must develop through practice the ability to keep the molten metal under perfect control. Practice on a discarded gear as follows:

First thoroughly clean the base of the broken tooth to remove dirt, oil and grease. Then grind the surface until bright

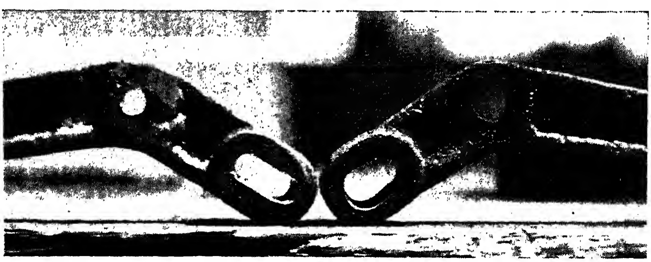


Fig. 86. Holes that become worn (right) are quickly built up with bronze and redrilled to original size (left).

metal is reached. Heat the base of the tooth with the blowpipe flame along its entire length until it is thoroughly warmed up. Applying the standard bronze-welding technique, tin the surface of the broken tooth and apply the first layer of bronze weld metal along the entire length. Then apply a second layer over

the first, making sure that it is thoroughly fused to the previous layer. See Fig. 84.

Some practice will be necessary before it will be possible to control the molten metal perfectly. There will be a tendency for the molten metal to run over the edge of the weld but by raising the blowpipe slightly as the edge is reached, the welder will soon be able to prevent this.

The succeeding layers should be added in the same manner until the entire tooth has been built-up. Throughout the operation the operator should endeavor to keep the contour as near as possible to that required for the finished tooth. This will minimize the amount of finishing and machining necessary. Experienced operators can rebuild an entire gear tooth so close to correct size and shape that practically no machining or finishing is required. See Fig. 85.

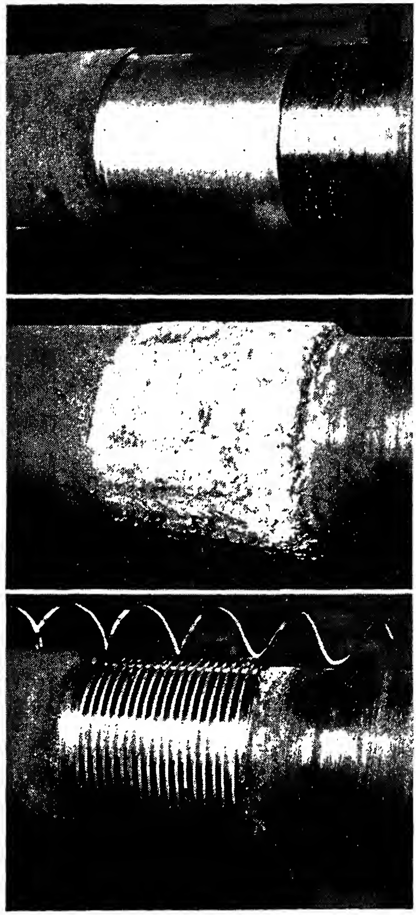


Fig. 87. Bronze-welding renews threads on paper mill pulp grinder shaft. The old threads were first machined off (top) to permit rebuilding the area with bronze (center); the finished job (bottom) and the chip indicate the soundness of the weld metal.

*Oversize Holes.* Holes and bushings that have become worn, out of round or oversize, can be quickly repaired by filling the hole completely with bronze and then redrilling to correct size. The part may be supported on a carbon block to provide a support for starting the building-up operation at the bottom of the hole. See Fig. 86.

The job illustrated in Fig. 87 affords a splendid example of the value of bronze-welding for rebuilding worn parts.

Through corrosion and wear, the threads on an 11-in. diameter steel shaft for a paper mill pulp grinder had become unfit for further service. The shaft was mounted in a lathe and the old threads machined off.

While still in the lathe, the section was preheated locally and then built-up with bronze. A 2-in. strip of bronze was first applied along the top surface parallel to the axis of the shaft. The shaft was then turned and a similar strip applied to the opposite side. This alternation was repeated until the entire surface was completed. The shaft was allowed to revolve all night while cooling.

New threads were then cut in the bronze-weld metal. The long chip in the lower illustration, Fig. 87, indicates the soundness of the weld metal and the ease of machining.

CHAPTER 19

# Welding Galvanized Iron

P*ROPERTIES.* Galvanized iron is used extensively for service conditions where uncoated iron or steel would be subject to corrosion. The coating of zinc which forms the galvanizing is applied by immersing the iron base material, whether sheet, pipe or other form, in molten zinc. A layer of flux on the surface of the zinc both cleans the iron as it enters the bath and insures a firmly adherent coating of zinc on the galvanized material. This process is known as hot-dip galvanizing.

Zinc has a relatively low melting point (786 deg. F.) and also has the property of volatilizing when heated. Consequently when galvanized material is heated the zinc coating does not melt and run on the surface as might be expected. Instead, the zinc vaporizes and burns, forming the familiar white fumes of zinc oxide.

*Avoid Inhaling Fumes.* As inhalation of these zinc oxide fumes may cause nausea, welding on galvanized iron should be done in well ventilated locations wherever possible. If it should be necessary to weld in confined spaces or if the job is of considerable duration, the operators should be supplied with suitable respirators. If the operator should experience any nausea while or after welding galvanized material, he should drink plenty of milk. Study Recommendations J-14 to J-16 in Chapter 40.

*Commercial Forms.* While galvanizing is applied to a wide variety of articles, galvanized sheet and pipe are the forms with which the welding operator will be most concerned.

The thickness of the coating on galvanized sheet varies from about 0.001 in. to 0.005 in. In the trade, the thickness is usually expressed in terms of ounces of zinc per square foot. Thus, a 2-oz. coating means that the total weight of zinc on both sides of the sheet is 2 oz. per sq. ft.

Galvanized pipe is coated inside and out. It is supplied in standard steel and wrought iron pipe sizes.

*Joint Design.* The joint designs for welding galvanized sheet and pipe are the same as for the uncoated materials.

*Preparation for Welding.* Any oil, grease or dirt along the joint should be cleaned off before welding but the galvanized coating should not be removed. Galvanized pipe can be beveled by means of the cutting blow-pipe as experience has shown that this does not seriously affect the coating.

Production welding of galvanized sheet is frequently done in jigs of the same general type and design as for other sheet metal products.

*Welding Methods.* Galvanized iron can be either fusion welded with steel welding rod or bronze-welded. As bronze-welding is done at a lower temperature, it has less effect on

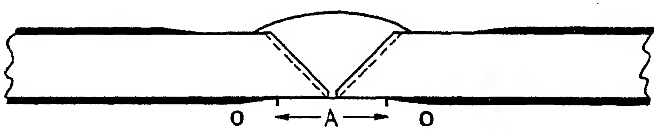



Fig. 88. Cross-section of galvanized iron showing the effect of fusion welding.

the galvanized coating than fusion welding, and consequently this method is preferred. Where fusion welding is used, it is generally advisable to paint the finished weld with aluminum paint or similar material. Bronze-welds in galvanized material give satisfactory corrosion resistance without painting, but this is sometimes done to give a uniform color to the finished product.

## FUSION WELDING GALVANIZED IRON

*Effect of Heat.* The effect of heat in fusion welding galvanized material may be visualized from a consideration of what happens in welding galvanized pipe.

In applying neutral flame fusion welding to galvanized pipe, using a steel welding rod, approximately the portion of the inside pipe wall marked "A" in Fig. 88 will become very hot due to the direct application of the flame on the reduced thickness of the beveled ends. In this type of welding where con-

siderable portions of the beveled ends would be melted and fused into the weld metal, it is safe to say that galvanizing is completely removed from the portion "A" on the inside of the pipe, as well as for a distance equal to or even greater than "½ A" beyond the limits of the weld on the outside of the pipe wall. More galvanizing is removed from the outside because of the more direct contact with the welding flame. On the inside beyond the width "A" galvanizing is gradually increased to the original thickness at such a point as "O" where the heat has not been intense enough to volatilize the zinc.

A steel fusion weld made by the Lindeweld process would produce a considerably narrowed band of zinc volatilization. The advantages of this process, greater speed and less heat involved in the fusion of the merest surface skin of the bevels, are particularly important in reducing the width of the band "A".

*Welding Technique.* The welding technique for fusion welding galvanized material is exactly the same as for the corresponding uncoated material, whether sheet or pipe.

Welding should, of course, be done with the minimum amount of heat consistent with good fusion.

*Finishing.* Fusion welds in galvanized material are usually given a coat of aluminum paint. Obviously it is not possible

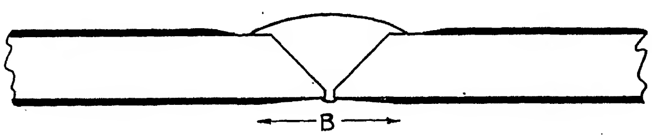



Fig. 89. Cross-section of galvanized iron showing the effect of bronze-welding.

to paint the inside of a welded joint in galvanzed pipe, but experience has shown that such joints give perfectly satisfactory service even without painting.

## BRONZE-WELDING GALVANIZED IRON

*Effect of Heat.* That the effect of heat is less in bronze-welding is graphically shown in Fig. 89, which represents a cross-section of the wall of a bronze-welded galvanized pipe.

The distance "B" approximately represents the width of a band around the inside of the pipe where the galvanizing will be at all affected. The effect will be negligible near the edges of this band with a gradual thinning of the galvanizing as the center of the weld is approached. For a short distance, perhaps ⅛ in. or 1/16 in., on each side of the center of the band the galvanizing may be completely removed from the abutting pipe ends. In many instances, however, a thin film of bronze spreads around the inside surface of the pipe much as solder will spread automatically on a properly tinned surface when the heat is right. This spread of bronze around the lower edge of the thin portions forming the vee protects the edges somewhat even though the galvanizing may be completely removed for a small distance back from the ends.

Fig. 90. Bronze-welding the longitudinal seam in a galvanized iron container. Observe the jig used to hold the edges of the seam in alignment.

In bronze-welding, the lower heat at the joint, and the character of the metal deposited all combine to give maximum protection from corrosion. No instances are known of premature failure of galvanized piping due to early corrosion of the welded joints.

*Welding Technique.* The welding technique for bronze-welding galvanized iron is exactly the same as for the corresponding uncoated materials.

*Finishing.* Bronze-welded joints in galvanized iron will give excellent service without any finishing. For some products, the finished bronze-weld may be coated with aluminum paint to give a uniform appearance.

## CORROSION RESISTANCE OF WELDED GALVANIZED PIPING

The question of corrosion resistance frequently arises in connection with welding, and particularly bronze-welding, galvanized piping. It results largely from the ungrounded belief that galvanic action should occur when dissimilar metals are in contact.

Experience in many different fields has shown conclusively that the accelerated corrosion which should result from galvanic action does not take place in the case of bronze in contact with steel, cast iron or galvanized iron.

Bronze-welded cast iron and steel pipe has been used for years subject to both external soil and internal corrosion and has led to no complaint of deterioration of the joint. Both steel welding and bronze-welding of galvanized piping has been practiced for many years, and to date there has been no evidence or complaint of accelerated corrosion at the joint as the result of welding. From the evidence at hand, it can be concluded that the possibility of galvanic corrosion can be dismissed from consideration in connection with the welding of galvanized material.

The phenomenon of electrolysis is sometimes confused with that of galvanic action, particularly where piping is buried underground. Electrolysis is generally considered as corrosion resulting from stray electrical currents, and shows itself principally as excessive deterioration where the current leaves the pipe. Welding is not a factor except that it improves the condition at the individual joints because the welded joint is an excellent conductor, localizing the corrosive effect only at the point where the current ultimately leaves the line which may not be a joint. Corrective methods for this are by grounding the pipe; a method well established through experience.

An important factor that is not generally considered when studying the welding of galvanized pipe is the comparison of the effect of welding and threading. Threading, of necessity, has been accepted as satisfactory. Often the galvanized pipe has to be cut and threaded for which, of course, the galvanizing is removed. Moreover, this occurs at the point where the wall thickness is materially reduced by the thread. In contrast,

welding, which does not remove any greater amount of galvanizing, does not reduce the wall thickness to shorten the life of the pipe.

In addition to giving full wall thickness at the joint, welding actually increases the resistance of the pipe against corrosion in the zone where the galvanizing is melted. Investigations made on welded steel pipe lines indicate that the weld and and adjacent base metal have higher corrosion resistance than the rest of the pipe. The heat of welding seems to cause the formation of a highly resistant oxide coating. Consequently, even though galvanizing is removed to some extent in welding, the exposed metal is more highly resistant to corrosion than that for threaded joints, since at the latter the area not only is robbed of the protective coating of the galvanizing, but is also reduced in wall thickness.

Practical experience thus shows that either fusion welded or bronze-welded galvanized pipe will give entirely satisfactory service.

CHAPTER 20

# Welding Cast Iron

*PROPERTIES of Gray Cast Iron.* Certain properties of ordinary cast iron make it of great value in the manufacture of a wide variety of metal products. When melted, cast iron is very fluid and the molten metal is also "long-lived," or slow to solidify, so it is possible to make castings of very intricate design. Water-jacketed cylinder blocks for automobile engines are typical of the complicated structures that can be produced with comparative ease. Additional factors contributing to the popularity of ordinary gray cast iron are its relatively low cost and the ease with which it can be machined. The latter is of particular importance in connection with parts that have to be produced in quantity.

Opposing all these good qualities, however, is the fact that gray iron castings are somewhat brittle. Bending or pulling strains, successive shocks or sudden temperature changes are quite likely to break them. From the viewpoint of the welding operator, this means that the ability to weld cast iron should be developed as an important part of his training.

The physical properties of cast iron are greatly improved by the addition of alloying elements, such as chromium and nickel. Alloy cast irons are used where service conditions are unusually severe.

*Composition of Cast Iron.* Anyone at all familiar with machinery realizes that there are several forms of cast iron. He may know in a general way the properties of gray iron, white iron and malleable iron. But the welding operator, in order to handle cast iron jobs successfully, must have a clear understanding of the fundamental factors which determine the physical properties of an iron casting.

Cast iron is by no means pure iron; it is a rather complex mixture containing 91 to 94 per cent metallic iron and varying

proportions of other elements, the more important of which are carbon, silicon, manganese, sulphur and phosphorus.

With the possible exception of sulphur, these elements should not be considered as impurities, for each has a definite influence on the properties of the cast iron. By varying the amount of these elements, the foundryman is able to produce a multitude of different irons, each with properties adapting it to certain uses.

*White Cast Iron.* Carbon is of primary importance. The proportion of carbon in cast iron generally lies between 2½ and 4 per cent by weight. In molten cast iron, this amount of carbon is completely dissolved in the iron, probably forming a chemical compound with the iron. If the molten iron is quickly cooled, this chemical compound chills and becomes solid but remains practically unchanged in its composition. It is customary to refer to the carbon in this compound as "combined" carbon. Examination of this quickly chilled cast iron will show it to be very hard and brittle, often impossible to machine. It will have a silvery white fracture; in short, it will be white cast iron.

*Gray Cast Iron.* If, on the other hand, the molten iron is permitted to cool quite slowly, the chemical compound of iron and carbon breaks up to a certain extent, and much of the carbon separates out as tiny flakes of graphite, scattered everywhere through the metal. This "graphitic" carbon, as it is called to distinguish it from "combined" carbon, gives the gray fracture which characterizes ordinary gray cast iron. Since graphite is an excellent lubricant, and the metal is everywhere shot through with tiny flaky cleavages, it is not difficult to understand on the one hand why gray iron is so easy to machine and on the other why it will not withstand a heavy shock.

*Malleable Iron.* When white cast iron is heated under certain suitable conditions to about 1,400 deg. F. for several days, the combined carbon separates not as flakes of graphite but as very fine rounded particles of carbon in the iron. This process tends to give castings more of the properties of pure iron; namely, high strength, ductility, toughness and ability to resist shocks. The product so made is accordingly known as malleable cast iron.

*Effect of Silicon.* The effect of the elements other than carbon may be summarized rather briefly. Up to 3 per cent, silicon tends to promote the formation of graphitic carbon and is thus important in producing gray iron. Silicon also increases fluidity of the molten metal and lessens casting shrinkage. Sulphur acts in the opposite manner, increasing shrinkage and preventing separation of graphitic carbon. To an extent, these harmful effects of sulphur may be overcome by the presence of sufficient manganese. Considerable phosphorus is used in intricate castings as it increases fluidity and decreases shrinkage, but at the expense of toughness; therefore this element is kept low in important castings carrying loads.

*Tests to Identify Variety of Iron.* A little practice will enable the welder to distinguish gray cast iron. Clean the edges of the break and examine the fracture. Gray iron is of uniform gray color throughout; white cast iron is silvery white and so hard it cannot be filed; malleable iron often has a dark center with white rim, and is generally much tougher than the other varieties. A continuous chip can be taken from the corner of a piece of malleable iron; cast iron will break as fast as chipped. See also Chapter 9.

## WELDING METHODS

*Gray Cast Iron.* Gray cast iron may be either fusion welded with cast iron welding rod, or bronze-welded. For the vast majority of cast iron welding jobs, bronze-welding is to be preferred as its lower temperature of application greatly simplifies the work.

Fusion welding is necessary where the color of the weld metal must match that of the base metal, as in reclaiming defective gray iron castings at the foundry; or where the part to be welded is subjected to service temperatures much over 500 deg. F. Bronze loses strength rapidly above this temperature.

*Malleable Iron.* Malleable iron must be bronze-welded. It cannot be fusion welded, as the malleable properties are completely destroyed when the metal is melted. The standard bronze-welding technique given in Chapter 18 should be used.

*White Cast Iron.* A white iron casting is seldom encountered by the welding operator. The material can be welded, if necessary, by the use of a white iron welding rod. This is some-

times done at malleable iron foundries for the reclamation of defective white iron castings that are to be subsequently malleabilized.

## Fusion Welding Gray Cast Iron

*General Principles.* To fusion weld gray iron so the completed job will actually be gray iron throughout requires special precautions. These may be expressed briefly in the statement: Gray iron castings should be heated to a dull red heat before welding, welded with correct welding rod, and then cooled slowly.

The reasons for this procedure should be apparent from the previous discussion of properties. Preheating the entire casting equalizes expansion and contraction stresses which might be sufficient to distort or crack the brittle metal if the heating were non-uniform or improperly controlled. Since less time is required to bring preheated metal up to welding temperature, there is a distinct saving in the amount of oxygen and acetylene required and of course less actual time will be required for welding. Preheating also makes it easier to anneal the casting —that is, to cool it very slowly, and thus allow the carbon in the newly added weld metal to separate as graphite. This means that the finished weld will then be soft, easily worked gray iron. Of course, a major function of annealing is to equalize or eliminate cooling stresses and internal strains. Great care must be taken to prevent sudden chilling of the casting, for this would produce white cast iron, brittle and so hard that machining might be impossible.

*Preparation for Welding.* The edges of the cast iron parts to be joined should be beveled to form a 90 deg. vee. On small parts this can be done with hammer and cold chisel or with a grinding wheel. Heavy sections can be beveled with the cutting blowpipe, or pneumatic chipping hammer.

In beveling ordinary thicknesses of cast iron, the vee should extend only to within ⅛ in. of the bottom of the break. This blunt bevel will make it easier for the welder to control the very fluid cast iron and build up a sound weld from the bottom with less danger of burning a hole through. Carbon blocks

may also be placed below any openings to prevent molten cast iron from running through.

Scale, cutting slag, rust, grease and dirt must be completely removed from the beveled edges by emery wheel, sand blast, wire brush or cold chisel. Neglect of careful cleaning results in porous spots and blowholes in the weld, when the impurities are of such nature or quantity that even the use of an excellent flux will not eliminate them. Cleaning should extend back from the edge of the vee for at least 1 in. on each side.

*Preheating.* For fusion welding cast iron, the general rule is that the entire casting should be preheated to a dull red before welding. Depending upon the size and shape of the casting and the location of the fracture, it is sometimes possible to confine the preheating to the section around the break. On large castings, such local preheating should not be attempted until sufficient experience has been gained to insure a thorough understanding of the effects of expansion and contraction.

Fig. 91. Fusion welding a lug on a cast iron automobile exhaust manifold. Observe the use of bar and clamp to hold the lug in alignment.

The action of preheating and annealing in assuring a true gray iron structure in the finished weld has already been discussed. Equally important is the effect of preheating and annealing in preventing strains that might be set up by expansion and contraction during welding, and in relieving such strains which have existed in the casting since it left the foundry—in fact, which probably had much to do with the crack itself.

Small cast iron parts may be preheated with the blowpipe flame. Larger parts should be placed in a temporary or permanent preheating furnace. (See Chapter 12.)

In preheating cast iron, the piece should be uniformly heated to a dull red and kept at this temperature during welding. The dull red heat is sufficient to give the desired results, yet low enough to prevent harm to the casting.

*Welding Rod.* Cast iron welding rod for fusion welding gray cast iron should be of special chemical composition so that the finished weld will have the desired properties. Certain elements, particularly silicon, tend to burn out during welding. The welding rod must contain sufficient silicon to insure the proper amount of this essential element in the weld metal. Oxweld No. 9 Cast Iron Rod is recommended for fusion welding gray cast iron.

*Flux.* A suitable flux is necessary in welding cast iron to render fluid the otherwise almost infusible slag of silicon dioxide mixed with iron oxide that forms on the molten cast iron puddle. Oxweld Ferro Flux is recommended as its use will insure clean, sound weld metal, free from inclusions that might cause porosity or blowholes.

*Welding Technique.* The technique for fusion welding cast iron can be learned by making practice welds in two small pieces of cast iron about ⅜ in. thick, each piece having a fairly straight edge 5 or 6 in. long. Bevel one edge of each piece to 45 deg. and clean the beveled surfaces with a stiff wire brush. Support the two pieces on firebrick placed on the welding table. A piece of carbon black placed just under the vee will help the beginner in controlling the molten metal.

*Blowpipe Manipulation.* Use a welding head or tip one size larger than for steel of the same thickness. Put on welding goggles. Light the blowpipe and adjust the flame to neutral. Play the flame along the sides of the vee until the entire joint has been thoroughly preheated. Then, starting at one end, direct the flame at the bottom of the vee until the metal there has melted. The flame should be pointed the same as in welding steel with the tip of the inner cone about ⅛ to ¼ in. from the metal.

When the bottom of the vee is thoroughly fused, the flame should be moved slightly from side to side, melting down the sides gradually so the liquid metal runs down and combines with the molten puddle at the bottom of the vee. If the metal gets too hot and tends to run away, raise the flame slightly.

The blowpipe should now be swung from one side of the vee to the other, keeping both sides melted as well as the bottom. The motion of the blowpipe is the same as in welding steel plate.

*Use of Welding Rod and Flux.* The end of a length of ¼-in. cast iron welding rod should be introduced into the outer cone of the flame, heated, dipped into the flux, and then placed with the end in the molten puddle. The heat of the molten metal on which the welding flame continues to play will melt the rod gradually, and the surface of the puddle will gradually rise with the addition of this metal.

The rod should never be held above the weld and melted drop by drop into the puddle. Also be careful to fuse the sides of the vee ahead of the advancing puddle, so the molten metal is never forced ahead onto colder metal. If the latter occurs it will cause an "adhesion" with little or no strength at that spot.

When gas bubbles or white spots appear in the puddle or at the edges, flux should be added and the flame played around the speck until the impurities float to the top. These are skimmed from the weld with the welding rod. Such impurities adhering to the hot rod are removed by tapping it against the table, thus eliminating them entirely. This removal of dirt must be done carefully and systematically, for impurities left in the weld will constitute defects and result in a joint of little strength.

The rod should be added to the molten metal until that section of the vee is built slightly above the level of the rest of the piece. When one section an inch or so long is built up, the bottom of the vee adjacent to it is next melted and the operation repeated. Of course, care must be taken to keep the end of the built-up section as well as the sides of the vee in complete fusion with the puddle.

*Slow Cooling.* Cast iron welding should be carried on as fast as possible. When finished, cover the completed weld with a piece of asbestos paper or bury it in the annealing bin so it will cool slowly.

*Testing Practice Weld.* When cold, brush the surface on both sides with a wire brush and carefully examine the weld. Notice particularly the appearance on the under side. If you have not secured thorough penetration and thorough fusion

between the edges at the bottom of the weld, you will be able to see this defect very clearly. The bottom of a good weld should show little round beads of weld metal protruding through, indicating that the operator has secured a good bond all the way to the bottom of the crack.

Now test the strength of the weld by clamping the specimen in a vise with the weld flush with the top of the jaws. Strike the upper end with a heavy hammer until the piece breaks. If the weld is a good one, the break should come in the base metal.

Then nick both sides of the weld with a hacksaw and fracture the piece through the weld so as to permit examination of the weld metal. The weld metal should be clean and sound, with no slag or oxide inclusions, or blowholes.

## SPECIAL CONSIDERATIONS FOR FUSION WELDING LARGE CASTINGS

The difference between welding small and large castings is not so much in the welding technique as in the amount of attention that must be given other factors. For successful welding of large gray iron castings, it is necessary to preheat them, weld while hot and then cool slowly.

*Preheating.* The preheating of large castings is usually done in a temporary firebrick furnace or in a permanent furnace.

*Local Preheating.* Often it will not be necessary to preheat the entire casting to secure the required expansion *at the break* (and subsequent contraction on cooling which tends to throw the weld metal under *compression).* For such local preheating, several types of preheating torches and fuel burners are on the market. A simple plumber's torch is often used on small castings. Oil and air burners, gasoline and kerosene torches, and the blacksmith or rivet forge are also used. If the forge is used, care must be taken not to burn one side by overheating.

*Control of Temperature.* The temperature should be watched carefully so that the casting does not get above a dull red. If the metal is heated too much it may warp by its own weight. Heavy castings which have no thin members may be preheated slightly hotter.

But if there are thin members in the casting, they come to

heat more rapidly than the thicker sections; care must therefore be taken not to get these so hot that they will get out of shape, because that portion must expand, yet is held back by the heavier part of the casting which may barely be at a black heat. To overcome this when using a charcoal-fired furnace, more

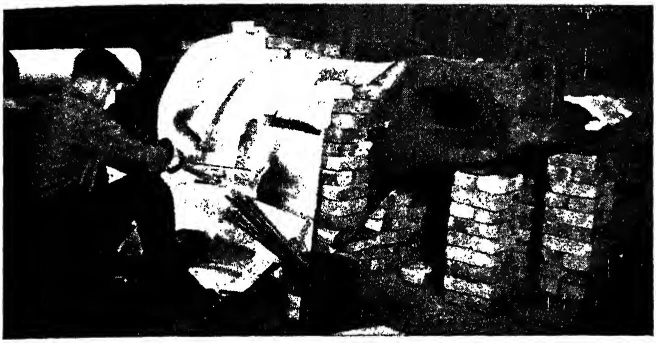


Fig. 92. Welding a punch press casting in a preheating furnace.

fuel may be placed around the heavier section, or the draft regulated to have the fire more intense around the heavier parts than around the lighter sections.

*Position of Part for Welding.* Arrange the work so the operator can reach the part to be welded. Think of this when arrangements are being made for preheating. The casting should also be so placed that the weight will not distort the metal when the casting is preheated, and so the heated casting will not be exposed to drafts or sudden cooling.

The correct alignment of intricate castings, particularly if they are composed of members of varying sizes, or if the weld is a complex one, will require thought and often considerable ingenuity. It should be borne in mind that correct alignment *after the weld is completed* is the end to be accomplished. Proper allowances for expansion and contraction during and after the welding must therefore be made.

As a means of checking alignment, it is advisable to make tram marks with a center punch on filed spots each side of the break. Measure accurately the distance between the tram marks before starting. This will give you a constant check on

the work and will quickly tell you whether the finished job is correct.

It is frequently necessary to use clamping devices of various types to hold the parts in proper alignment for welding. If the break is of such a nature as to require turning of the casting during welding, suitable means must be provided *beforehand* as the handling of a large red-hot casting is a matter requiring careful consideration.

*Reheat After Welding.* During welding the additional heat from the blowpipe flame causes an uneven heat in the casting, the metal around the crack now being hotter than that further from the weld (which. in fact, may necessarily be out of the fire and cooling off). Consequently, after welding is finished, it is important to cover the entire casting with fresh charcoal and bring the piece up again to an even heat throughout.

*Cool Very Slowly.* Then cover the furnace with asbestos paper and allow the casting to cool and contract evenly in the dying fire. It is important that one part does not cool quicker than any other, for then the piece may crack due to an uneven "pull" in contracting.

When the casting is slowly cooled, weld metal made from suitable cast iron welding rod will be easy to machine.

*Testing the Finished Weld.* It is desirable to have some proof of the soundness of the finished weld, but a complete test would involve destruction, as would also be true of a similar test of the original casting.

How did the manufacturer of the casting know that it was sound? By carefully following foundry practices that experience had shown would produce good castings. The welding operator can do the same. By making practice welds and testing them, he will soon reach a point where he can make a cast iron weld and feel quite certain that it is sound.

There are certain non-destructive tests that will give some indication of the character of the weld. For example, water jackets or steam jackets in castings can be easily tested by using water at a pressure somewhat higher than the working pressure required. While the jacket is under hydrostatic pressure the weld should be tapped lightly with a hammer. This will bring out possible hidden stresses.

When a large casting is swung off the ground and struck with a hammer, any part in which there are locked up stresses will produce a sound of higher pitch than the rest of the casting.

The presence of very small leaks or pin holes in castings that cannot be subjected to hydrostatic test can often be discovered by applying kerosene to one side of the weld. Kerosene has the property of quickly working its way through very small pores. The appearance of a kerosene stain on the other side of the weld will indicate the location of any pin holes.

## Bronze-Welding Cast Iron

Bronze-welding offers many advantages as a means of welding cast iron. As it does not require melting the base metal, it completely eliminates the considerations which are necessary to insure the proper gray iron structure in a fusion weld. Because of the lower temperature required, preheating is greatly simplified. Preheating of the entire casting is seldom required. The use of only local preheating at a relatively lower temperature makes it possible in many cases to effect repairs to broken machines in place. This saves the time and expense of dismantling and reassembly, and is an important reason for the constantly increasing use of bronze-welding. See Fig. 93.

*Preparation for Welding.* Beveling and cleaning should be done as for cast iron fusion welding. It is preferable to avoid machining in beveling cast iron for bronze-welding, as the machining operation tends to spread the graphite flakes over the surface in such a way as to interfere with proper "tinning" action. However, a machined cast iron surface will "tin" readily if it is first heated to a dull red temperature with the blowpipe flame. This heating or "searing" removes the small flakes of graphite that were exposed by the machining operation.

All parts should be carefully aligned and clamped into alignment. This should be done before preheating. Depending upon the size and nature of the part, the entire casting or the section in the vicinity of the weld is brought to a black heat. For large and complicated castings particularly those with

several fractures, the proper sequence of welding operations should be studied in advance, with due consideration for the effects of expansion and contraction. While these effects are much less than for fusion welding, they must not be disregarded.

*Welding Technique.* The standard bronze-welding technique (Chapter 18) should be used. There are several useful hints in connection with work on castings. Sometimes a casting that has been exposed to fire, such as a boiler section, will

Fig. 93. Bronze-welding a large cement mill crusher housing without dismantling.

be found difficult to tin. This is because the constant exposure to heat and fire causes a change to take place in the surface of the cast iron itself. This effect can be overcome by spreading a strong oxidizing agent such as powdered potassium chlorate on the part of the joint just ahead of the weld puddle, when it is heated to a red color. As soon as the effervescence ceases, the regular tinning will proceed easily and rapidly. This oxidizing of the cast iron surface leaves a normal gray iron surface easy to work on. Brazo flux should be used as usual for the bronze-welding operation.

One of the features of the bronze-welding of cast iron is that in a great many cases it is unnecessary to dismantle a piece of broken machinery for repairs. Such work, however, often necessitates welding in a vertical direction. If the crack itself runs in a vertical direction the work should be started at the bottom, first building up a little shoulder to start the bronze layer. Then the work can be carried upward always having the completed weld as a support for the molten weld metal.

If the crack runs horizontally along a vertical surface, a small shoulder of bronze can be built up on the clean iron surface just below the crack and parallel to it. This will give a firm foundation to work on and the bronze-welding of the crack itself then becomes an easy matter.

*Slow Cooling.* Following the welding operation, the blowpipe should be played rather generally over the surface of the metal over a considerable area surrounding the weld in order to bring unequally heated sections of the base material to an even heat. The casting should then be covered with asbestos paper (or if small enough, buried in dry slacked lime) and allowed to cool down slowly. It should be protected from drafts which might cause uneven cooling.

## Cast Iron Pipe

*Types.* There are two general classes of cast iron pipe in use: gray cast iron pipe employed extensively for underground water and gas lines; and alloy cast iron pipe containing small percentages of nickel and chromium, furnished in sizes and wall thicknesses corresponding to extra heavy steel and wrought iron pipe, and used for special piping services.

*Welding Methods.* Gray cast iron pipe is customarily bronze-welded, both in the foundry or shop, or under field conditions.

Chrome-nickel cast iron pipe is usually welded in the foundry with rod of the same composition as the base metal. It may also be bronze-welded in the shop or on the job.

### BRONZE-WELDING CAST IRON PIPE

*Joint Design.* The strength of a regular vee joint varies from 75 to 90 per cent of the strength of the cast iron pipe.

To develop the full strength of the pipe, a special joint design should be employed. This is known as the "shear-vee" joint since the shelf in the design provides for increased bond between the bronze and cast iron in direct shear. See Fig. 94.

*Preparation for Welding.* After pipe ends have been machined to form the vee, the bevels should be heated to a dull red temperature by means of a ring burner, a furnace or by

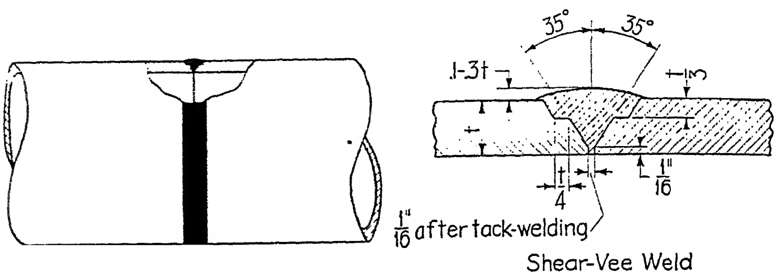



Fig. 94. Shear-vee joint for bronze-welding cast iron pipe.

heating the ends all around with an oxy-acetylene blowpipe. This is necessary to remove the small flakes of graphite which are exposed by the machining operation, and which would otherwise seriously interfere with the tinning action and reduce the strength of the bond between the bronze and the cast iron.

The joints should be lined up and held in alignment by means of three or more small tack-welds. Spacing before tack-welding should be just sufficient so that at no time during welding shall the ends of the pipe come together.

*Welding Technique.* The standard bronze-welding technique (Chapter 18) should be followed. Forehand technique should be employed and flame and welding rod manipulation should be such as to produce a distinct ripple effect on the surface of the completed weld. The position of rod and flame is similar to that for welding steel pipe.

For vertical and overhead welding, the technique should be modified just as in welding steel pipe. The puddle must be kept as shallow as possible, and reliance placed upon the pressure of the flame to keep the puddle in place.

Welded joints in cast-iron pipe should be protected from drafts while cooling.

## WELDING CHROME-NICKEL CAST IRON PIPE

Chrome-nickel cast iron pipe is usually cast in short lengths which are joined into longer lengths at the foundry by welding with cast iron rod.

*Joint Design.* The open single vee butt type joint should be used.

*Preheating.* Best practice requires that joints in pipe larger than 3 in. in diameter should be preheated.

*Welding Rod.* Welding rod may be of the same composition as the base metal, furnished by the pipe manufacturer, or for most uses a good quality cast iron welding rod, such as Oxweld No. 9 Cast Iron Rod, will be satisfactory.

Fig. 95. Making a shear-vee bronze-welded joint in cast iron pipe.

*Flux.* A flux is required for the fusion welding of cast iron because oxides which form on the puddle surface must be kept fluid so they will not interfere with the welding operation. Oxweld Ferro Flux is recommended.

*Welding Technique.* The procedures to be followed are similar to those for welding steel and wrought iron pipe with forehand technique. The walls of the vee should be broken down perceptibly by the flame as the puddle advances to insure complete fusion of the weld metal to the pipe ends. Slight reinforcement only is required. The pipe should be turned during welding to keep the puddle in the best position for satisfactory work. Joints should be protected from drafts during cooling.

*Bronze-welding.* For many uses of chrome-nickel cast iron pipe bronze-welded joints are just as satisfactory as fusion welded joints from the standpoint of service and corrosion re-

Fig. 96. Installing a bronze-welded cast iron water line.

sistance. Bronze-welded joints can be made in the shop or on the job by following the procedures recommended for gray cast iron pipe.

CHAPTER 21

# High-Carbon Steel and Certain Alloy Steels

FROM the standpoint of oxy-acetylene welding, steel containing over 0.70 per cent carbon may be considered as high-carbon steel. This includes the high-carbon machine steels, springs, cutlery and nearly all common tools.

The special properties of high-carbon steels are usually developed by heat-treatment. The heat of welding will naturally affect the heat-treated base metal in the zones immediately adjacent to the weld. Overheating may affect the base metal in such a way that the original properties can not be restored by any subsequent heat-treatment or forging. Consequently the welding of high-carbon steel should not be undertaken without a thorough knowledge of the specific properties and correct heat-treatment of the material under consideration.

It is usually advisable to preheat high-carbon steel before welding. Oxweld No. 1 High Test Steel Welding Rod is recommended. An excess acetylene flame should be used and care should be taken to avoid overheating the base metal. The quality of the welded joint will be greatly improved if it is subsequently heat-treated.

*Welding Without Fusion.* For certain purposes, fusion welding of high-carbon steel can be avoided by the use of bronze or cast iron welding rod—either of which melts and makes a good joint at the sweating temperature of the high-carbon steel. Thus, composite lathe tools have been made with a high-speed steel bit welded with cast iron welding rod to an alloy steel shank. The operation closely resembles bronze-welding in its method of manipulation. Bronze could not have been used here instead of cast iron because subsequent heat-treatment of the tool would have melted out the bronze.

*Nature of Alloy Steels.* Alloy steels contain, in addition to carbon, one or more metals such as nickel, chromium, vanadium

tungsten, manganese, or molybdenum. Many of these alloy steels develop physical properties that make them superior to plain carbon steels, *only* after they have been heat-treated under carefully controlled conditions. Welding will, of course, destroy the effect of heat-treatment in the zone adjacent to the weld.

*Subsequent Heat-Treatment.* With the majority of alloy steels it is possible to restore the properties by heat-treating again after welding; but to do this properly requires equipment that is beyond the average welding shop. Such alloy steels should therefore be welded only in plants having the most modern facilities for heat-treating. Welding of such parts as alloy steel automobile axles or steering knuckles should never be attempted; owing to the effect of the welding heat, the welded section will not be as good as the rest of the metal, nor as good as required for safe operation of the machine to which it belongs.

*Exceptions.* Manganese steel is an exception owing to the fact that the heat-treatment is relatively simple and can be done by following the method to be outlined later, unless the part is large and complicated.

There are also certain low alloy steels, particularly the Cromansil steels, which have excellent strength in the as-rolled condition and which do not require special heat-treatment. These are readily welded by the methods given later in this chapter.

The corrosion-resisting steels containing chromium either alone or in combination with nickel, are also weldable. These are considered in Chapter 22.

## WELDING MANGANESE STEEL

*Properties.* The wear-resisting properties of steels containing a high percentage of manganese are so satisfactory that these steels are being used with increasing frequency for many parts that are subjected to excessive shock or abrasion. Due to the extremely severe duty expected of such alloys, they are frequently subjected to overloads which are too great to be withstood even by these tough alloys. The constant abrasion which these steels often encounter eventually results in wear-

ing away of the steel to the extent that building-up of the worn surface becomes necessary. Consequently, the repair and rebuilding of manganese steel parts is a subject of interest in many industries.

The manganese steel most commonly used for resistance to shock and abrasion has a manganese content of from 12 to 14 per cent and is commonly called Hadfield steel. Hadfield steel has a higher coefficient of expansion and lower thermal conductivity than has plain carbon steel, properties that must be constantly kept in mind during welding.

Manganese steel castings require heat-treatment in order to develop their desirable physical properties. When first studied, the problem of welding this steel presented difficulties because the high temperature involved tended to change the physical nature of the metal somewhat and also nullified the effect of the original heat-treatment. However, careful investigation proved that it is possible to weld this alloy provided the proper procedure is carefully followed.

*Preparation for Welding.* To prepare a casting for welding, the edges should be beveled to a 90 deg. total vee. This should be done either by grinding or by cutting with the oxy-acetylene blowpipe. If cut by the latter method, the edges should be ground or pickled to remove any adhering oxide.

*Preheating.* The casting should then be prepared for welding by preheating in a manner similar to that used for ordinary cast iron. Large castings should be heated slowly in a charcoal-fired preheating furnace made of firebrick while for small castings a kerosene preheating torch or the welding blowpipe may be used. Since manganese steel is brittle in the temperature range of 840 to 1,830 deg. F. the work should be carefully supported during preheating and welding. Welding should be done in the preheating furnace, care being taken to protect the casting from drafts or sudden chilling while hot. If preheating is done with the welding blowpipe, the casting should be protected by covering it with sheets of asbestos paper.

*Welding Rod.* A welding rod with a manganese content equal to or slightly greater than that of the base metal should be used.

*Welding Technique.* The blowpipe flame should be adjusted

to show a slight excess of acetylene. A comparatively large welding tip should be used and a fairly large puddle of melted metal should be maintained continually. The rod should not be rubbed in the weld; the end of the rod should be kept under the surface of the puddle and the blowpipe flame applied to melt the rod in the puddle of molten metal. When the puddle has been built-up sufficiently, it should be melted in the base metal by directing the flame around the edges until the weld metal and the base metal flow together through their own fluidity. Care must be taken, however, to avoid building-up too large a puddle, because it may flow over onto the solid metal with the result that there will be no fusion between the weld metal and the base metal.

*Heat-Treatment.* If the weld may be required to withstand a considerable amount of stress the entire casting should be reheated to a uniform temperature of about 1,940 deg. F. held at this temperature for about 30 min. and then quenched in water. Pouring water on the heated metal is not sufficient; for proper heat-treatment, the casting should always be entirely immersed in the water.

A sound weld made under these conditions will give satisfactory results where an unusual amount of strength in the welded part is not required; it will be entirely satisfactory for resistance to abrasion and to a considerable amount of shock, which is the reason for using this alloy.

## WELDING CROMANSIL STEELS

*Properties.* Where moderately priced steels having properties superior to plain carbon steels are required, Cromansil steels are being used to a large extent and fulfill every requirement. These easily manufactured open hearth steels, containing chromium, manganese and silicon, extend the possibilities of alloy steel usage into many industries because of their relatively low cost.

The range of composition of Cromansil steels most widely employed at the present time contain from 0.4 to 0.6 per cent chromium, 1.1 to 1.4 per cent manganese and 0.7 to 0.9 per cent silicon, with the carbon content varying from less than 0.10 to 0.25 per cent.

In the as-rolled condition steel with this combination of alloys has better physical properties and higher strengths than any type of plain carbon steel. Strengths as high as 100,000 lb. per sq. in. in the as-rolled condition are obtainable. In addition, high fatigue limit, great ductility and high impact strength can be obtained in the as-rolled condition. A fatigue limit as high as 60 per cent of the ultimate strength can be procured.

*Weldability.* An important factor in the performance of Cromansil steels is their ease of welding and the good strength of welded joints obtained. By the use of the correct rod and welding technique, strong, tough welds are made as easily as in ordinary steel.

*Welding Procedure.* The welding procedure as well as the choice of welding rod depends on the thickness of the Cromansil sheet to be welded. For thin sheets 1/8 in. and less in thickness, forehand welding, in which the flame points toward the unfinished part of the seam, is recommended. By this technique better control of the weld and greater speed are possible. Oxweld No. 32 CMS steel welding rod is recommended for welding Cromansil steel in all thicknesses. Cromansil steel plate 3/16 to 1/4 in. thick should be beveled so as to form a 90 deg. vee; plate 3/8 in. and heavier should be beveled to form a 70 deg. vee.

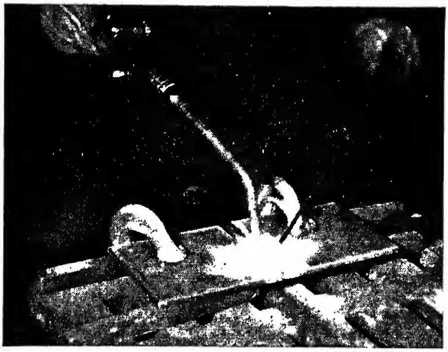


Fig. 97. Making a practice weld in Cromansil steel plate.

For relatively thick material, the backhand method of welding, in which the flame points toward the finished part of the seam, is recommended. Control of the fusion in the bottom of the weld and along the sides of the scarf is easier to obtain with backhand welding, and also the hot gases pass back along the completed portion of the weld and retard the cooling, with

consequent reduction in hardening of the weld and adjoining base metal.

Smaller sizes of welding tips are recommended for overhead and vertical welding and the extent of change will depend somewhat on the experience and skill of the operator in making these types of welds.

Overheating of the melted weld metal should be avoided, especially when the Cromansil steel contains 0.25 per cent carbon or more. If the welder has difficulty with overheating, a smaller tip than that recommended can be used; and for these higher carbon Cromansils, normalizing the weld at a temperature of 1,650 deg. F. will give the best results.

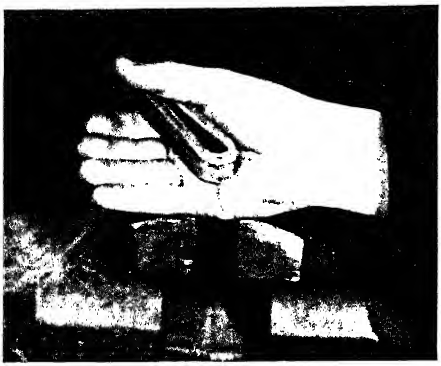


Fig. 98. Bend test indicates the strength and ductility of weld and base metal.

Experience has shown that properly made welds will have even greater strength than 0.10 carbon Cromansil base metal, and the ductility will be such that in the free bend test the per cent elongation in the outside fibers will be on the order of 30 per cent. In the 0.20 per cent carbon Cromansil steel, the strength of the welds when made properly will be about the same as the base metal, and the elongation in the bend test about 20 per cent.

## CHAPTER 22

# Welding Corrosion-Resisting Steels

ALLOYS of iron and steel containing chromium, either alone or in combination with nickel, form a most important group of corrosion-resisting metals. Because of their exceptional resistance to many types of corrosion, these alloys, which include the familiar stainless steels, are finding increasingly wide application in the chemical, food products, dairy, brewing, oil refining and many other industries.

Welding is widely used in fabricating these high-chromium alloys, as it adds the factors of strength, permanence and neat appearance to the finished product.

*Welding Procedures.* As the welding procedure for high-chromium alloys is governed largely by the chromium content, the alloys may be conveniently divided into several groups. The presence of large amounts of chromium in these steels necessitated several changes in welding methods that were entirely predictable from a knowledge of the nature of the metal chromium.

*Flame Adjustment.* Chromium, at high temperatures, has a marked affinity for both oxygen and carbon. Translating this to the welding of high chromium steels, it is evident that flame control is exceedingly important. An oxidizing flame would remove chromium from the metal as chromium oxide and produce unsound, brittle welds. Use of an excess acetylene or reducing flame would promote the formation of chromium carbides which also would remove valuable chromium from the metal. The most satisfactory flame adjustment is therefore the neutral one with no excess of either oxygen or acetylene.

*Flux.* Not only is chromium metal easily oxidized when molten, but the oxide is very infusible, with the result that when formed during welding, it will act as an insulating blanket between the flame and the work and care must be taken to keep the amount formed as small as possible. The use of a flux with a high solvent power for chromium oxide is essen-

tial. Careful flame control plus minimum puddling and with no excess heating will keep the amount of oxide low, and by using a specially designed flux the objection to chromium oxide formation may be practically eliminated. Best results are obtained through the use of Oxweld Cromaloy Flux, which is especially designed for welding high-chromium steels.

*Heat-Treatment.* It will be observed that certain types of high-chromium alloys require heat-treatment or annealing after welding. Obviously, the welding of such alloys should be done only in shops which have adequate facilities for giving the necessary heat-treatment.

GROUP I—4 TO 7 PER CENT CHROMIUM STEELS

| | |
|---|---|
| Chromium | 4 to 7 per cent |
| Carbon | About 0.10 per cent |

This group consists of steels containing from 4 to 7 per cent chromium, with or without additional elements, as molybdenum or tungsten.

Early experience with welding the 4 to 7 per cent chromium steels indicated that these steels were air-hardening, with the result that the weld metal and particularly the zone adjacent to the weld became hardened. The air-hardening was often accompanied by brittleness which complicated the welding, sometimes requiring expensive preheating or annealing procedures.

Since the air-hardening property of these steels was known to be due to the presence of chromium carbide, an extensive investigation was made to find other elements, with a marked affinity for carbon, which would "lock up" that troublesome element in the form that would make it unharmful. The two semi-rare elements columbium and titanium were found particularly effective for this purpose.

The addition of columbium or titanium to the 4 to 7 per cent chromium steels prevents air-hardening, and greater ductility is obtained, even in the as-rolled condition. These steels may be satisfactorily welded with a rod containing columbium and 6 to 8 per cent chromium.

The presence of either columbium or titanium also reduces the annealing time to minutes instead of the hours often re-

quired for steels not bearing these elements. Because of this effect, marked improvement in ductility can be obtained in the weld by a simple blowpipe anneal. This consists in heating the weld with the blowpipe to a red temperature (1,475 to 1,650 deg. F.) for 1 or 2 min. The softening range varies from 1,300 to 1,650 deg. F. so the annealing can be performed without difficulty.

GROUP II—RUSTLESS OR STAINLESS IRON

| | |
|---|---|
| Chromium | 11.5 to 15 per cent |
| Silicon | Max. 0.50 per cent |
| Manganese | Max. 0.50 per cent |
| Carbon | Max. 0.12 per cent |

Irons of this class are used in a variety of forms. In thicknesses up to 16 gauge, flange type welds are ordinarily employed. All scale should be removed from the edges to be welded. The flanges, preferably about 1/16 in. high, are painted top and bottom with a paste made by mixing Cromaloy flux with water. After this the weld is made in the usual way by melting down and fusing the flanges. A blowpipe tip just large enough to insure proper fusion should be used, since too large a tip would cause the molten metal to boil and would result in porous welds.

For thicknesses greater than 16 gauge, welding rods of the same composition as the base metal, or low carbon rod containing 15 to 18 per cent chromium will produce welds with satisfactory corrosion resistance for the conditions under which this metal is generally used. Good butt type welds can be obtained in metal 1/16 in. to 1/8 in. thick without beveling. Thicknesses greater than 1/8 in. should be beveled. It is essential that the flux be applied to the line of the weld on both the top and bottom surfaces of the sheet. This prevents oxidation on the under side and allows good fusion and union to take place under the protecting film of slag. Without the use of this flux, it will be impossible to obtain complete fusion at the bottom of the seam. The rod also may be painted with a thin mixture of Cromaloy flux and water. When this is done, it is only necessary to paint the bottom sides of the seam with flux.

In making welds in heavier gauges of rustless iron, the plate should be beveled for a single vee type weld and the both faces of the bevel coated with the flux. The welding should be carried through to completion rapidly.

*Annealing.* As a result of the high temperature attained during welding, rustless iron has a tendency to be brittle in the weld metal and in that portion of the sheet adjacent to the weld unless properly heat-treated after welding. Rustless irons, particularly those containing 12 to 14 per cent chromium, are subject to air-hardening, and require annealing to restore toughness to the weld and base metal adjacent to the weld. Best results are obtained by heating in a furnace at a temperature of 1,250 to 1,300 deg. F. followed by slow cooling, either in the furnace or in warm still air.

The blowpipe is often utilized for applying the heat in cases where it is not possible to use furnaces. When using this method of annealing, care must be exercised not to heat the metal above the maximum temperature previously mentioned. The benefit to be derived from blowpipe annealing will depend on the care used in controlling the temperature and time of heating. Usually three minutes within the above temperature range will give the desired softening effect.

*Bronze-Welding.* Although the bronze-welding of rustless iron is not generally recommended because it causes brittleness, it can be done, if desired. A mixture of 75 per cent Cromaloy flux and 25 per cent Brazo flux should be used.

Where other than a fusion weld is desired, silver soldering is preferable to bronze-welding. A suitable flux for silver soldering rustless iron consists of a mixture of equal parts of boric acid and potassium fluoride or potassium acid fluoride.

## GROUP III—STAINLESS IRON

| | |
|---|---|
| Chromium | 15 to 18 per cent |
| Silicon | Up to 1.50 per cent |
| Manganese | Max. 0.50 per cent |
| Carbon | Under 0.12 per cent |

In this group best results will be obtained by the use of a welding rod of the same composition as the base metal. A splendid weld also can be made with 18 per cent chromium-

8 per cent nickel welding rod. The metal adjacent to the weld is subject to some grain growth but annealing at 1,200 to 1,350 deg. F. will improve its ductility. With careful welding, the grain growth is kept to a minimum.

The presence of columbium or titanium in these steels makes them more amenable to hot working and forming operations, improves their physical properties after welding and therefore widens their field of application.

Here again as in the case of rustless iron, Cromaloy flux should be used to insure uniform results. The technique and procedure outlined for Group II for the actual welding operation should be used.

### GROUP IV—18 PER CENT CHROMIUM-8 PER CENT NICKEL ALLOY

| | |
|---|---|
| Chromium | 16 to 20 per cent |
| Nickel | 7 to 12 per cent |
| Silicon | Up to 1.50 per cent |
| Manganese | Max. 0.65 per cent |
| Carbon | Max. 0.12 per cent |

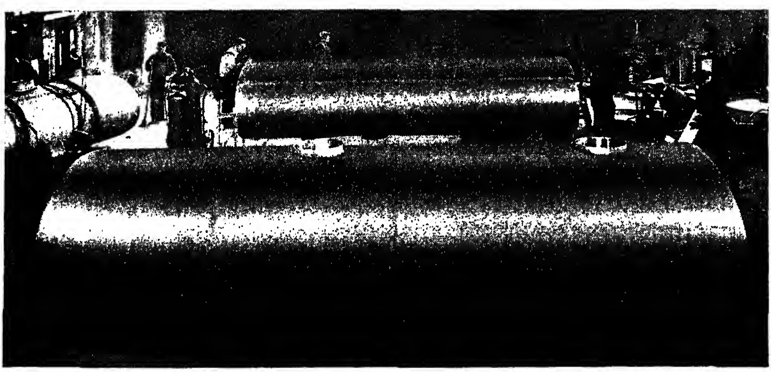


Fig. 99. Fabrication of oxwelded stainless steel tanks.

The group of alloys containing 18 per cent chromium and 8 per cent nickel comprise the austenitic stainless steels commonly known as 18-8.

*Treated 18-8.* Where the welded products will be subjected to conditions of severe corrosion or oxidation, particularly at

elevated temperatures, it is recommended that 18-8 stainless steel bearing either columbium or titanium be used as base material and that welding be done with Oxweld No. 28 Columbium-Bearing 18-8 Welding Rod. Welded joints made in this way have full corrosion resistance in the as-welded condition; they do not require any heat-treatment after welding. This is an important advantage in many cases where it would be difficult to heat-treat the welded product.

The 18-8 stainless steel has a high coefficient of expansion, which accentuates its tendency to warp. This difficulty can be controlled by jigs or other fixtures to hold the sheets in place during welding and at the same time limit the heat absorbed by the base metal. Careful preheating of large surfaces in special jigs is sometimes used to prevent distortion during welding.

Before starting to weld, the underside of the seam should be painted with a thin paste of Cromaloy flux and water. In welding light gauge sheet, it is helpful to put flux on the welding rod as well.

Fig. 100. The use of columbium-treated rod perfects the welded fabrication of this stainless steel refrigerator box.

Welding should be done with a neutral flame. Puddling of the weld should be avoided as it has a tendency to cause oxidation. The preferable welding technique consists in holding the rod ahead of the blowpipe so that the molten metal melts in place or is melted simultaneously with the base metal.

Under normal welding conditions, the columbium in the columbium-bearing welding rod is retained in the weld metal with only a slight loss. Overheating of the molten weld metal should be avoided as this would result in a loss of columbium.

Wherever possible, joints should be welded toward an edge. If it is necessary to weld away from an edge, begin the weld

an inch or two in from the edge and return to this point later to complete the weld to the edge.

For thicknesses ⅛ in. and over, it is often advisable to weld by the backhand method since it minimizes distortion. With columbium-bearing base metal and welding rod, the greater length of time that the weld zone is held at a red heat with backhand technique causes no carbide precipitation.

*Untreated 18-8.* Columbium-bearing welding rod can also be used to advantage in welding the straight 18-8 stainless steels which do not contain either columbium or titanium. Where these steels are subject to only moderately corrosive action, they will give satisfactory service in the as-welded condition.

### GROUP V—24 PER CENT CHROMIUM-12 PER CENT NICKEL ALLOY

| | |
|---|---|
| Chromium | 20 to 30 per cent |
| Nickel | 10 to 22 per cent |
| Silicon | Up to 1.50 per cent |
| Manganese | Up to 1.50 per cent |
| Carbon | Max. 0.25 per cent |

These steels are considered the best at present known for applications requiring optimum resistance to corrosion associated with high creep strength and resistance to oxidation at high temperatures. They are of the austenitic type and for many applications they should be stabilized by adding elements such as columbium or titanium. In general, the welding procedure should follow that given for the 18-8 stainless steels in Group IV.

### GROUP VI—CHROME IRON

| | |
|---|---|
| Chromium | 23 to 30 per cent |
| Manganese | Up to 1.00 per cent |
| Silicon | Max. 0.50 per cent |
| Carbon | Max. 0.25 per cent |

The welded chrome iron will not stand severe mechanical treatment at ordinary temperature, but is quite ductile at temperatures above 932 deg. F., and as this is its principal service, namely, to resist oxidation at very high temperatures, welded joints can be used wherever desired.

Chrome iron, as this alloy is commonly called, has about the same coefficient of expansion as steel and accordingly about the same allowance should be made for expansion and contraction. Welding rods of the same composition as the base metal should be used. The edges of the weld should be prepared the same as for steel of like thickness. In order to secure good bottom fusion the application of a paste of Cromaloy flux to the underside of the seam will prevent atmospheric oxidation and allow the bottom edges to fuse together. Without flux on the underside severe oxidation will take place, leaving a groove at the bottom of the weld. A small amount of flux applied to the rod will facilitate welding in preventing oxidation of the rod at the end. In making a weld only enough heat to secure satisfactory fusion should be used. Overheating causes boiling and results in porosity. The welds should be made as rapidly as possible and should be carried through to a finish without delay.

This alloy is subject to a coarse grain structure. This is especially true of ingots and castings which are cast at excessively high temperatures or held at a high temperature for a long time. This condition may be corrected by the presence of high nitrogen in the alloy, which refines the grain, and makes the alloy more ductile, even after welding.

In welding castings it is preferable to preheat, and weld with a rod of same composition as the base metal, using as little heat as possible and a neutral flame. If the castings are high in carbon, as in castings for wear resistance, the use of an excess acetylene flame is permissible. It will facilitate the welding, allowing sand and oxide to be floated more easily. Any blowholes should be ground out, if possible, exposing clean surfaces for welding. Slow cooling, after welding, is advisable. If heat-treatment is required to impart special properties to the casting, this should be done after cooling down from the welding operation; or, the casting after welding may be brought up to the desired uniform temperature without allowing it to cool down. This last procedure will eliminate stresses from uneven cooling. Annealing after welding is recommended.

## GROUP VII—CASTINGS

High chromium alloy castings, with wide variation in contents of chromium or chromium and nickel, are in extensive use. They may contain also appreciable amounts of silicon. Castings, as a rule, contain considerably more carbon than the rolled products. The castings may be used for resistance to chemicals, heat, or wear, the composition being determined by the use.

For welding castings containing high carbon and designed for wear resistance, it is preferable to preheat to a good red heat to avoid cracking the metal. Cooling should be relatively slow; after this the castings may require further heat-treatment to produce the necessary hardness. Welding rods of the same composition as the base metal should be used. The use of flux will facilitate fusion and assist in removing oxide and sand spots in defective castings.

After welding, the casting should be reheated to an even temperature and cooled slowly. Following this, further heat-treatment may be necessary in order to produce the desired physical properties in the metal.

CHAPTER 23

# Welding Aluminum

CHARACTERISTICS. As the behavior of aluminum under the welding flame is quite different from that of steel, a distinctive welding technique is required. Once the differences in behavior and technique are thoroughly understood, however, it will be found that aluminum is one of the easiest metals to weld.

Aluminum has a relatively low melting point, 1,215 deg. F. for the commercially pure metal. The thermal conductivity is high; aluminum conducts heat more than four times as fast as steel. This means that when heat is applied to the metal at any point, it is carried away and dispersed rapidly throughout the body of the metal.

Because of its light color and low melting point, aluminum does not give any indication by a change in color that the metal is approaching the welding heat. When the melting point is reached, the metal collapses suddenly. By observing the behavior of aluminum as it melts under the action of the blowpipe flame, the operator will quickly learn how to control the rate of fusion.

The surface of a molten puddle of aluminum oxidizes rapidly, forming aluminum oxide which has a higher melting point than aluminum. In order to make a sound weld, this oxide must be removed. It is customary to use for this purpose a suitable flux which combines chemically with the aluminum oxide to form a fusible slag that rises to the surface of the puddle where it is readily removed.

Another property that must be considered is the fact that aluminum and many of its alloys are weak when hot, in other words they are hot short. This means that due care must be taken to see that aluminum parts are adequately supported when hot. The aluminum-silicon alloys are unusually free from hot shortness.

## COMMERCIAL GRADES OF ALUMINUM AND ITS ALLOYS

Aluminum and its alloys are made in a large number of different grades. Those which can be satisfactorily welded are commercially designated as follows: high purity; the common grades 2S and 3S; the high strength, heat-treated alloys 51S and 53S; and the casting grades.

*High Purity Grade.* This grade, which contains more than 99.5 per cent aluminum, is used for certain special purposes where an exceptionally high purity of metal is required.

*Common Grades.* The grade known as 2S is the commercially pure aluminum, containing a minimum of 99 per cent aluminum. It is one of the easiest forms to weld. The low manganese alloy, 3S, contains about 1.25 per cent manganese with a minimum of 97 per cent aluminum. This is another of the easily welded forms.

The 2S and 3S materials come in several conditions of cold work hardness, ordinarily designated as follows: O, annealed; ½ H, half hard; ¾ H, three-quarters hard; and H, hard. The effect of these various tempers on the tensile strength is shown in Table I.

In the case of 2S and 3S in any of the H tempers, the metal is annealed by welding. The resulting joint should then be considered as having strength on the same order as the soft temper metal, or as in the O condition. Cold hammering the joint after welding will increase the hardness temper to a degree.

*Strong Aluminum Alloys.* Among the wrought strong aluminum alloys which depend upon heat-treatment for their strength characteristics, two types, designated as 51S and 53S, can be welded satisfactorily. Each of these types is available in different modifications or tempers according to the exact heat-treatment given during manufacture. Welding is not recommended for joining strong aluminum alloys of types other than these two specified.

Type 51S is a silicon-magnesium-aluminum alloy. It is a readily welded, heat-treated alloy of considerable strength. The alloy 53S also contains silicon and magnesium. It has good corrosion resistance, weldability and strength.

*Casting Alloys.* The aluminum casting alloys cover a rather wide range of composition. Generally speaking, the more common casting alloys which are not heat-treated can all be satisfactorily welded either in fabrication or in repair.

## JOINT DESIGN

Although the joint designs for welding aluminum and its alloys are in general principle the same as for steel, there are certain differences which make advisable a detailed discussion.

*Flange Type Joint.* The flange type joint can be used for aluminum sheet 16 gauge and lighter. The flange should be

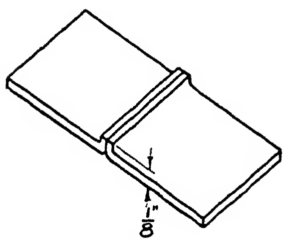



Fig. 101. Flange type joint.

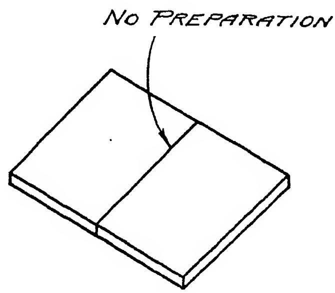



Fig. 102. Butt type joint.

about the same height as the thickness of the sheet or slightly higher. Before welding the upturned edges of the flange should be painted with flux. See Fig. 101.

*Butt Type Joint.* Aluminum sheet up to 17 gauge can also be welded with a plain butt type weld. This requires no preparation of the sheet edges. Before welding, flux should be painted along the edges of the sheet. See Fig. 102.

*Notched Butt Type Joint.* For aluminum from 17 to 7 gauge in thickness, it is recommended that the edges of the sheet be notched through their entire thickness, the notches being approximately $\frac{1}{16}$ in. deep and $\frac{3}{16}$ in. apart. The notches are best made with a cold chisel. These notches aid in obtaining full penetration. Flux works down to the full thickness of the sheet. There is less chance of melting holes through the sheet

and the notches also act as small expansion joints to prevent local distortion. See Fig. 103.

*Lap Type Joint.* The lap type joint is not recommended for aluminum unless conditions are such that no other type of joint can be used. A single lap should never be used as it is practically impossible to remove flux and oxide particles that have been left along the enclosed side of the weld in this type of joint. In all aluminum welding it is essential to remove all traces of flux after welding in order to prevent subsequent corrosion of the joint.

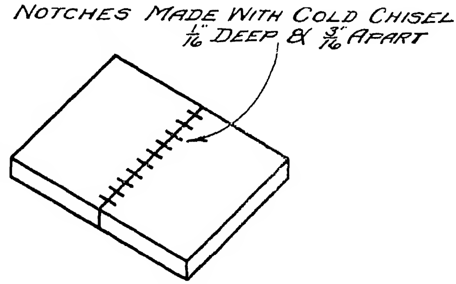



Fig. 103. Notched butt type joint.

If it should be necessary to make a lap type joint, a double lap weld should be used. Both overlapping edges should be welded completely to the adjacent metal. Then care should be taken to seal in the ends of the joint so that no moisture can get in between the overlapped pieces. By doing this the oxide and flux which cannot be cleaned off between the sheets will not affect the corrosion-resisting qualities of the welds, for no air can get at them. See Fig. 104, which shows the double lap weld with a seal weld at the end.

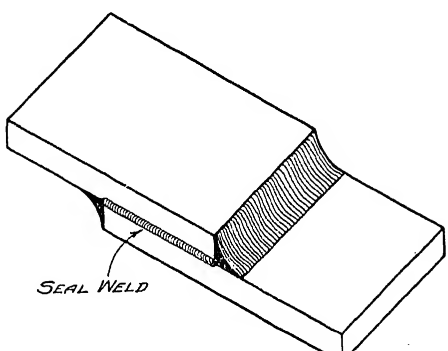



Fig. 104. Lap type joint.

*Single Vee Notched Butt Type Joint.* For welding aluminum plate material 3/16 in. and heavier, the edges should be beveled to form a vee having an included angle of 80 to 90 deg. The vee should not extend through the entire thickness of the plate but a shoulder of about 1/16 to 1/8 in. should be left at the

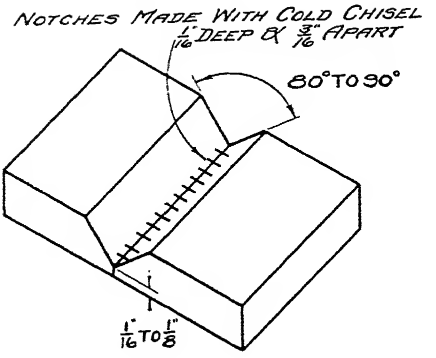



Fig. 105. Single vee notched butt type joint.

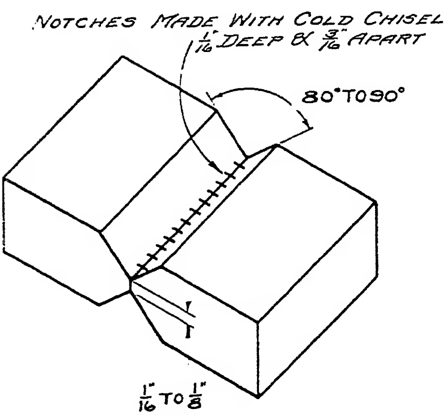



Fig. 106. Double vee butt type joint.

base of the vee. This shoulder should be notched before welding, the notches being approximately 1/16 in. deep and 3/16 in. apart. See Fig. 105.

*Double Vee Butt Type Joint.* For material 7/16 in. thick and heavier, a double vee butt type joint should be considered as an alternative to a single vee type. The included angle for the bevel should be 80 to 90 deg. An unbeveled shoulder of 1/16 to 1/8 in. should be left in the center of the joint. This unbeveled shoulder should be notched. See Fig. 106.

*Modified Single Vee Type Joint.* It has also been found that for material 7/16 in. thick and heavier, a modification of the single vee type weld is useful. The edge preparation is the same as for the single vee type joint with the exception that notching is not used. When the weld has been completed, the underside of the weld is chipped out to about 10 or 15 per cent of the plate thickness. This groove is then welded. See Fig. 107.

## PREPARATION FOR WELDING

*Preheating.* Even in the case of sheet aluminum it is good practice to warm up the entire sheet with the blowpipe flame before welding. This decreases the effect of expansion.

It is customary to preheat aluminum plate 3/8 in. or more in thickness before welding. Preheating can be done with a second oxy-acetylene blowpipe or by a city gas or kerosene torch.

Preheating is particularly recommended for welding aluminum castings. Small castings can be preheated satisfactorily by means of the welding blowpipe flame. For large or complicated castings general preheating in a suitable temporary or permanent furnace is recommended, at least until the operator becomes expert. As experience is gained the operator will find that for most work he can eliminate preheating in a furnace and do local preheating by means of the blowpipe.

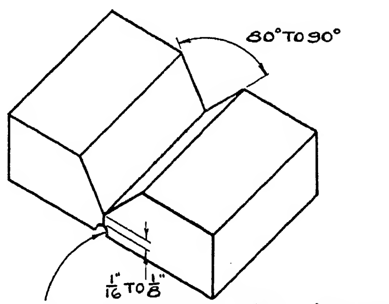



Fig. 107. Modified single vee type joint.

Whenever aluminum is heated, its hot shortness should be kept in mind and ample provision should be made to support the part so as to prevent collapse. Care should also be taken in preheating to avoid overheating as aluminum has a relatively low melting point.

*Cleaning.* Before repair welding aluminum parts that have been in use, the edges of the part should be thoroughly scrubbed with a wire brush and gasoline to remove any grease, oil or dirt which may be on the surface.

## WELDING ROD

Selection of welding rod for welding aluminum is dependent upon the composition of the base metal.

For high purity aluminum, high purity wire or strips cut from the base metal should be used.

For welding 2S and 3S aluminum, Oxweld No. 14 Drawn Aluminum Rod is recommended.

For welding the heat-treated alloys 51S and 53S, and for welding all types of aluminum castings, Oxweld No. 23 Aluminum Rod is recommended. This is a special aluminum alloy rod possessing high strength, good corrosion-resisting prop-

erties, and unusual freedom from hot shortness. It has a low melting point and a wide melting range. Because this range is greater than that of pure aluminum and most of the other aluminum alloys, the weld metal remains molten or at least plastic after the base metal has solidified. In this way stresses caused by contraction which might otherwise on cooling cause cracking of the base metal are shifted to the plastic weld metal.

Weld metal from Oxweld No. 23 aluminum welding rod should not be heat-treated at temperatures above 940 deg. F. on account of its low melting point. For this reason, where subsequent heat-treatment of one of the aluminum alloys is to take place after the material is welded, at a temperature greater than 940 deg. F., a welding rod of the same composition as the alloy is recommended. When this is used, allowance must be made for expansion and contraction.

## FLUX

In welding aluminum, the use of a specially prepared flux is necessary in order to remove the aluminum oxide which forms rapidly on the molten weld metal. Oxweld Aluminum Flux is recommended for all aluminum welding.

Aluminum flux is sold as a powder and is best prepared for application by mixing with water to form a thin paste of free flowing consistency. It is then applied to the welding rod by means of a brush. Some operators prefer to place the flux mixture in a container in the form of a long slender tube of aluminum, brass, or glass. The welding rod is simply dipped into the container before use. The mixture should be stirred frequently. Steel cannot be used as a container because it contaminates the flux mixture.

Where no welding rod is used, as on flange joints in thin sheet, the flux is painted on the flanged edges. For welding heavier material, the flux is applied both to the welding rod and to the base metal. By painting the seam on both sides, an ample quantity of flux will be assured.

After welding is finished, it is important to remove all traces of flux that may be adhering to the surface. If the flux were allowed to remain on the surface, it might cause subsequent corrosion.

## WELDING TECHNIQUE

The fundamental welding technique for aluminum is practically the same for sheet, plate or castings. The basic features of technique are given in this section and certain special considerations relating to castings and heat-treated alloys are treated separately.

*Melting Characteristics of Aluminum.* Before attempting to weld aluminum for the first time, it is advisable to become thoroughly familiar with the action of the metal under the welding flame.

Place a small piece of sheet aluminum on the welding table, light the welding blowpipe and adjust the flame with a slight excess of acetylene. With the flame held perpendicular to the surface of the sheet, bring the tip of the inner cone almost in contact with the metal. Observe that without warning the metal suddenly melts and runs away leaving a hole in the sheet. Now repeat the operation with the blowpipe flame held at an angle of about 30 deg. to the plane of the surface. With a little practice, you will be able to melt the surface metal without forming a hole. Now try moving the flame slowly along the surface of the sheet, melting a small puddle. Observe how quickly the aluminum puddle solidifies when the welding flame is removed. Continue this practice until you are able to control the melting with considerable facility. Then proceed with practice in actual welding, starting first with simple flanged and notched butt type joints which do not require welding rod. Then proceed with the use of the welding rod, at first for sheet and thin plate and subsequently for castings. Be sure to use flux. Do not attempt to weld the heat-treated alloys until considerable experience has been gained in aluminum welding technique.

*Technique.* The basic features of aluminum welding technique are given in the following paragraphs. Before starting to weld, the joint should be properly prepared, the welding rod selected and flux provided in accordance with the recommendations previously given.

Because of the high heat conductivity of aluminum and the rapid rate of welding, it is advisable to use a blowpipe head or

tip one size larger than that ordinarily used for welding steel of the same thickness.

The blowpipe flame should be adjusted so as to have a very slight excess of acetylene. The flame should be of low gas velocity and soft, never "blowy" and harsh.

In welding, the blowpipe should be held at an angle of about 30 deg. to the plane of the weld. This will avoid blowing holes through the heated metal. The end of the inner cone of the flame should be held about 1/8 in. away from the metal.

The blowpipe flame should be directed so that it heats both the edges of the joint and the end of the welding rod. Both sides of the joint must receive an equal amount of heat to produce even and smooth welds. When starting the weld the two edges should begin to melt before welding rod is added. The correct time to start moving along the seam is quickly learned by the operator with a little practice. The welding rod should be held in a direct line with the weld. The tip of the rod is held in the flame near the metal and it is necessary to direct a considerable portion of the flame on the rod itself as the molten pool of aluminum will not melt the rod as is the case in steel welding.

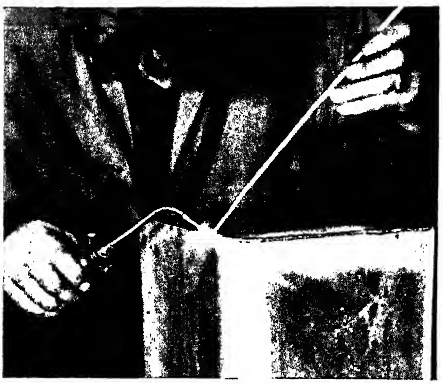


Fig. 108. Welding corner joint in a sheet aluminum container.

Metal from the welding rod should be fused thoroughly with the base metal as it is added. The weld can be built up above the surface of the base metal if desired.

It will be observed that only a small portion of the metal is molten at any one time. As soon as the flame is withdrawn the puddle solidifies. Inasmuch as fusion takes place very rapidly, the weld progresses quickly along the seam.

It is generally better to complete the weld in one operation. Should a section prove to be faulty and have to be replaced,

chip out the old weld metal and reweld with new metal. An exception to this is found in welding 2S and 3S aluminum over $\frac{3}{16}$ in. in thickness. Here layer welding is recommended. The first or bottom layer is put in fairly shallow followed by a second layer to finish and give reinforcement.

*Finishing Welds.* As soon as the work has had time to cool off after welding, it should be thoroughly treated to remove all traces of adhering flux. A steam jet is effective for certain classes of work. In some plants the custom is to wash in a hot 2 per cent nitric acid solution or a warm 10 per cent sulphuric acid solution. Immersion for about 20 min. in this solution follows a soaking for about 3 min. in hot water, during which the welded joint is thoroughly scrubbed with a brush to remove all visible traces of flux. A similar rinsing takes place after the acid bath.

Fig. 109. Repairing a cast aluminum vacuum cleaner part.

Welded aluminum products are quite frequently put into use without any finishing, such as machining or grinding. If desired, the weld can be made almost invisible by grinding off excess metal or by hammering the seam. Grinding is usually done where products are to be subsequently polished. Hammering should not be done however, in the case of the heat-treated alloys.

## WELDING ALUMINUM CASTINGS

All types of aluminum castings can be readily welded with Oxweld No. 23 Aluminum Welding Rod and Oxweld Aluminum Flux, using the basic technique outlined in the preceding section.

As noted on page 193, preheating is necessary in welding aluminum castings.

As aluminum does not show heat the way steel does, some

method of determining the proper preheating temperature is necessary. There are several ways in which this can be done. If a stick drawn across the metal chars and leaves a black mark, the casting is hot enough. Or if sawdust thrown on the work chars and becomes black, the casting is ready for welding. Cast alumnium heated thoroughly will give off a dead sound in contrast with the ring of a cold casting. Aluminum sweats at a heat about right for welding, small beads appearing on the surface. The metal should feel soft when scraped with the end of a cold welding rod. Welds in castings should usually be reinforced about 1/4 in. After the work is completed the casting, whether in a preheating furnace or not, should be covered with asbestos paper or some other heat insulating material to prevent it from cooling too rapidly. It should remain covered until stone cold. It can then be ground or filed to finish.

## WELDING STRONG ALUMINUM ALLOYS

The strong aluminum alloys 51S and 53S can be welded in the annealed and heat-treated tempers. As indicated previously, welding is not recommended for other types of high strength aluminium alloys.

*Types of Heat-Treatment.* While these high strength aluminum alloys are occasionally used in the annealed or cold worked tempers, they are ordinarily used in the heat-treated tempers. The two general heat-treatment tempers are designated by the letters "W" and "T". The process of heating these alloys up to a temperature of 970 deg. F., and quenching in cold water is known as solution heat-treatment. The material so treated is designated as being in the "W" temper. By subjecting the material to an additional heat-treatment or aging the mechanical properties of the alloy can be further improved. This process consists in holding the material at 320 deg. F. for 18 hr. The material is then designated as being in the "T" temper. The effect of these heat-treatments on the tensile strength of 51S and 53S is shown in Table I.

*Effect of Welding on Heat-Treatment.* Welding obviously has no effect on the strength of material in the annealed or O condition. In welding alloys in the W or T tempers however, the heat of welding does remove some of the effect of heat-treatment and the strength of the finished joint is intermediate

between that of the unwelded base metal and of metal in the annealed condition. Thus welds in 51SW and 53SW not heat-treated after welding can be expected to give a tensile strength of about 22,000 lb. per sq. in. By heat-treating after welding a portion of the properties lost can be regained, and consequently this should be done wherever possible.

*Welding Procedure.* Blowpipe manipulation, flame adjustment and tip size are practically the same for welding these alloys as for the other grade materials. The preparation of the joint by veeing and notching is also the same and flux is applied in a similar manner.

Oxweld No. 23 Aluminum Welding Rod is recommended for welding the high strength alloys 51S and 53S. It should be remembered, however, that because of the low melting point of this rod the weld metal should not be heated above 940 deg. F. For this reason, where it is desired to heat-treat parts after welding at temperatures in excess of 940 deg. F., a welding rod of the same composition as the alloy should be used. When this is done full allowance must be made for expansion and contraction.

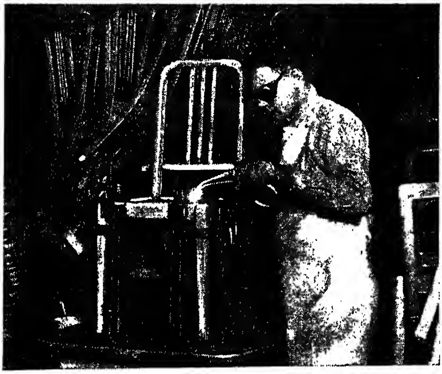


Fig. 110. Fabricating chairs from strong aluminum alloy tubing.

These heat-treated alloys should be welded in one pass. Reheating the weld metal to add a second layer is undesirable particularly on metals that are to be water-tight or gas-tight. In addition, welding in one pass is generally faster and more economical.

*Jigs and Fixtures.* Where jigs or fixtures are used they must be designed so that the parts will be free to expand and contract. It is important to make certain that contraction of the parts as they cool does not place undue stress on the weld. One method is to tack-weld the parts in the jig and then loosen the clamp before completing the welding. Frequently it is suffi-

cient merely to loosen the jig clamp immediately after completing the joint.

*Heat-Treatment After Welding.* Wherever possible the entire part should be heat-treated after welding. It should be placed in a suitable furnace, heated to a temperature of 890 to 970 deg. F., depending on the alloy and then quenched in cold water. The time of heating may range from 15 min. to 1 hr. depending upon the method of heating and the size of the article. Air quenching is permissible if water cannot be used.

Where no heat-treating is to be done after welding, the welded part can be allowed to cool in the air.

*Coated Alloys.* The special group of alloys which consist of a strong aluminum alloy coated with pure aluminum to resist corrosion can be welded in exactly the same manner as the strong alloys mentioned above.

TABLE I

TENSILE STRENGTH OF ALUMINUM AND ALUMINUM ALLOYS

| | Average Tensile Strength, lb. per sq. in. | | | |
|---|---|---|---|---|
| Temper | 2S | 3S | 51S | 53S |
| O (annealed) | 13,000 | 16,000 | 16,000 | 15,000 |
| ½H | 17,000 | 21,000 | | 22,000 |
| ¾H | 20,000 | 25,000 | | |
| H (hard) | 24,000 | 29,000 | | 28,000 |
| W (heat-treated) | —— | —— | 35,000 | 32,000 |
| T " " | —— | —— | 48,000 | 38,000 |

CHAPTER 24

# Welding Copper

D*ISTINGUISHING Characteristics.* Copper is a red metal. A casting of pure copper is soft and tough and very malleable. Pure copper wire or sheet is much harder and stronger than copper ingots or castings—the work required to produce these forms (often done cold) hardens and strengthens the metal in direct proportion to the amount of rolling, forging or drawing. But copper is always softer than steel. It can be hammered out cold into a thin edge.

About the best test is the color. Copper has a peculiar color ranging from rose-pink to red on a freshly broken surface, which is hard to imitate.

Some soft brasses and bronzes look something like copper, although the color has a yellowish cast if some tin is present. They can be readily distinguished by melting them under the blowpipe, using a neutral flame. Brasses will give off white fumes of burning zinc. Bronzes may not smoke enough to see, but they usually contain enough volatile metal so the cold frozen puddle will have a ring of whitish or yellowish crust surrounding its edges.

*Weldability of Commercial Copper.* Commercially pure (electrolytic) copper contains from 0.01 to 0.08 per cent of oxygen in the form of an oxide, cuprous oxide, which is not enough to harm its properties, *except for fusion welding.* Early attempts to make fusion welds in commercially pure copper were somewhat unsatisfactory as it was found that almost invariably a zone of weakness developed in the base metal immediately adjacent to the welded joint. Several years ago careful metallurgical investigations of the weldability of copper showed conclusively that the small amount of cuprous oxide present in the base metal was responsible for the difficulties encountered in welding. This cuprous oxide is present in the form of small particles which, as a result of the forming and annealing operations during manufacture, are distributed

within the grains of the metal. Hence, in well-made copper sheet and bars, the metal is strong, tough and ductile because the oxide is uniformly distributed in the grains and a break occurs through or across the tiny crystalline grains, rather than along the surfaces or boundaries of the grains making up the pieces.

When, however, this copper is welded, the metal in a zone adjacent to the weld is heated to a temperature at which a change in the grain structure of the metal takes place and the small particles of oxide separate or segregate at the grain surfaces or boundaries. This causes a zone of weakness because in this area a break will occur along the surfaces of the grains rather than through them.

These results immediately suggested that if copper entirely free from cuprous oxide were used for welding, the previously encountered difficulties would entirely disappear. Further investigations showed that this conclusion was entirely correct.

*Deoxidized Copper.* As a result of these investigations completely deoxidized copper can now be bought from leading producers in a variety of forms. Deoxidized copper should always be specified in ordering copper for welding.

Deoxidized copper is made by adding a small amount of silicon (manganese, phosphorus or boron have also been used) to the metal in the process of manufacture. Silicon robs the copper almost instantly of its last trace of oxygen. A slight excess of silicon is used, so a little remains alloyed in the copper and furnishes protection during welding.

*Test for Weldability.* The weldability of a given sample of copper may be tested by heating a piece of it to a bright red. just below the melting point, and then hammering it vigorously on an anvil. If it breaks, it contains cuprous oxide and is consequently unsuitable for fusion welding. Such metal—that is, commercially pure copper—can be joined satisfactorily by means of bronze-welding. See p. 204.

*Welding Methods.* For fusion welds in copper, completely deoxidized copper base metal and welding rod should be used. A special copper alloy rod, such as Oxweld No. 19 Cupro Rod, will also give satisfactory results. For many of the commercial applications of copper, bronze-welding affords a satisfac-

tory method of joining. Here again the use of deoxidized copper is recommended wherever possible but bronze-welding can be used to produce joints of satisfactory strength in ordinary commercially pure copper.

*Joint Designs.* Joint designs for welds in copper sheet, plate, castings, etc., are in general the same as for steel of similar thickness. Copper pipe is discussed in a separate section in this chapter. See p. 204.

## FUSION WELDING TECHNIQUE

For fusion welding deoxidized copper with deoxidized copper welding rod, the welding technique is very similar to that employed for steel. A neutral flame is used and no flux is required. The welding head or tip should be one or two sizes larger than for a similar thickness of steel because of the high heat conductivity of copper. Wherever possible it is advisable to cover the work with asbestos paper in order to reduce heat losses to a minimum. Large sections should always be preheated to a dull red before welding and, wherever practicable, the same practice should be followed even for small parts. After a few trials the welding operator will automatically make such minor modifications in technique as are made necessary by the relatively low melting point of copper and by the fact that the molten puddle is more fluid or "runny" than steel.

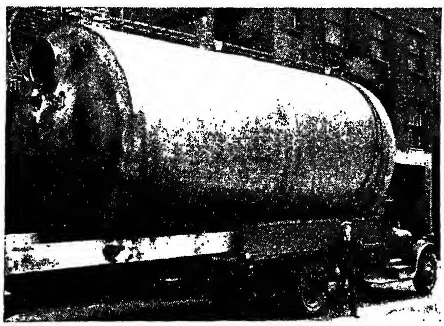


Fig. 111. Fusion welded copper tank for acetic acid storage.

A special copper alloy welding rod (Oxweld No. 19 Cupro) whose melting point (1,920 deg. F.) is only slightly less than that of pure copper (1,981 deg. F.) may also be used for fusion welding of copper. With deoxidized copper of high quality, this welding rod will give welds having an average tensile strength of about 25,000 lb. per sq. in. With average commercial

copper which is not deoxidized, the average tensile strength of the welds will be from 15,000 to 17,000 per sq. in.

The technique for fusion wielding copper with the special copper alloy rod is the same as that for deoxidized copper welding rod.

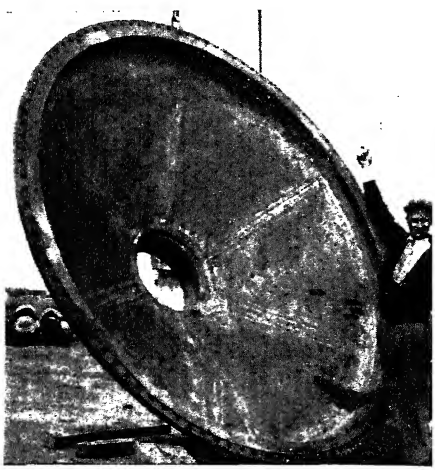


Fig. 112. Copper lining in dished head for petroleum refinery still, completely oxwelded with a special copper alloy welding rod.

## BRONZE-WELDING COPPER

For joining copper in many of its industrial and domestic applications, the speed and economy of bronze-welding may be utilized to advantage. Indeed bronze-welding offers distinct advantages for the great majority of copper welding work. The major exceptions are where it is necessary that the color of the weld metal exactly match that of the base metal, and where the difference in chemical composition between bronze-weld metal and copper base metal might be undesirable from the standpoint of corrosion. The standard bronze-welding technique (Chapter 18) is used in bronze-welding copper.

## WELDING COPPER PIPE

*Types.* Copper pipe may be obtained in standard iron pipe sizes in both regular and extra heavy wall thicknesses. Copper pipe and tubing for plumbing and heating and for various industrial uses are also supplied in a wide range of sizes, wall thicknesses and degrees of hardness. Many of these sizes and grades are supplied particularly for use with the solder-type fittings.

*Welding Method.* Copper pipe may be fusion welded using either deoxidized copper welding rod or the special copper alloy rod mentioned above. For most services, bronze-welding

of copper pipe is to be preferred because of its greater ease, speed and economy. The joining of copper pipe by means of solder-type fittings is discussesd in a separate section in this chapter.

*Joint Design.* Joint designs for fusion welding and bronze-welding copper pipe are in general similar to those for equivalent thicknesses of steel pipe. For line joints the open single vee butt weld shown in Fig. 115 is recommended for all diameters and for all positions of welding.

For copper pipe having a well thickness of 1/8 in. or less the short-bell type joint shown in Fig. 115 is sometimes employed.

Fig. 113. Fabricating thin walled pipe from copper sheet by bronze-welding.

Copper welding fittings such as welding elbows and Van Stone welding stubs can be secured in standard sizes. Other fittings such as tees, branches, crosses, etc., can be readily fabricated as is done in steel pipe work. In the chemical and process industries, copper piping is frequently used with Van Stone flanges for connecting to valves.

One large chemical company has found it practical and economical to fabricate Van Stone flanges on copper tubing for low pressure service. The end of the copper tubing is first heated slightly with an oxy-acetylene blowpipe flame and then peened over against the flange with a wooden mallet. The gasket face is finally finished off smooth with a fine file.

*Preparation for Welding.* For line joints of the butt type where the pipe wall is 3/16 in. or more in thickness, the ends should be beveled as shown in Fig. 115. Spacing prior to tack-welding will usually be slightly less than for steel pipe of equivalent diameter and wall thickness.

Various means may be used for the preparation of the short-

bell type line joint. The pipe end may be flared out by driving a tapered plug into the pipe or by hammering with a wooden mallet on the horn of an anvil. The spigot end may be chamfered to 75 deg. by means of a file, grinding wheel or machine tool.

*Welding Technique.* For either fusion welding or bronze-welding copper pipe the techniques discussed above should be followed.

A difference in welding technique is observed when the bell type joint is used, or where a branch connection is made with branch smaller than the main. These require fillet welds, for which the flame must be directed more on the pipe forming the spigot in the case of a line joint or more on the main in the case of a branch connection to secure an even welding heat.

## COPPER SOLDER-TYPE FITTINGS

Recently special copper fittings of the so-called solder-type have come into wide use for joining copper pipe in plumbing and heating work and in certain industrial applications. These solder-type fittings are threadless and slip over the pipe with a very close tolerance. By means of an internal groove or feed channel connected with an external feed hole, solder can be melted into the heated fitting in such a way that liquid solder is drawn by capillary attraction into the space between the fitting and the pipe, forming a tight joint. These fittings are largely used for low temperature service and the solder can be most advantageously applied by means of the air-acetylene flame discussed in Chapter 34.

Quite recently the use of the solder-type copper fittings has been extended to other industrial services where ordinary solder cannot be used because of its inability to resist corrosion and heat. Thus solder-type copper fittings have been successfully used with silver solder which has a melting point of about 1,300 deg. F., and for still higher temperature service with bronze welding rod, which has a melting point of about 1,650 deg. F.

As these temperature ranges are beyond the heating ability of the gasoline blow torch or the simple air-acetylene flame, except for small sizes of pipe, the oxy-acetylene blowpipe flame is used. It has been found that these fittings work just

as well with these high-melting point solders and welding rods as with the lower melting point solders for which the fittings were originally designed.

The fitting is slipped over the pipe and the fitting and adjacent piping are then heated with an oxy-acetylene blowpipe flame to a temperature higher than the melting point of the hard solder or bronze welding rod to be used. Flux is applied and the rod is melted into the joint, where it is drawn in and around evenly by capillary attraction.

# CHAPTER 25

# Welding Brass and Bronze

*Nature of Alloys.* The brass alloys are those in which copper and zinc are the essential components, the zinc content ranging from 15 to 40 per cent. Ordinary machine brass contains 60 to 68 per cent copper and 32 to 40 per cent zinc, whereas the red brasses contain from 75 to 85 per cent copper, the remainder being zinc. Intermediate alloys frequently contain 1 per cent or more of tin, manganese, iron or lead.

A bronze may be of almost any copper base composition, but as a usual thing this term is reserved for alloys containing relatively high percentages of tin and lead with or without small amounts of zinc. Typical compositions are: 90 per cent copper and 10 per cent tin; 85 per cent copper, 5 per cent tin, 5 per cent lead, and 5 per cent zinc; 88 per cent copper, 10 per cent tin, and 2 per cent zinc. In addition, there are a number of miscellaneous alloys such as those containing various amounts of nickel, which gives the alloys a whiter color. Practically all these compositions are found in either cast or rolled condition, and a number of them are extruded into a wide variety of special shapes.

*Welding Methods.* For general industrial purposes bronze-welding is widely used to produce perfectly satisfactory joints in most of these alloys. For the more recent applications, particularly those involving the use of extruded brasses and bronzes as well as castings and forgings in ornamental work, fusion welds are often preferable and in some cases the only type of welding possible. To be satisfactory for this type of work, the welds must have certain definite characteristics, among which the most important are: (1) the weld metal must be perfectly sound and free from porosity so that the joint will not be perceptible on a polished surface; (2) the weld metal must, in many cases, not only match exactly the color of the

base metal at the time the weld is made, but the color of the weld metal must follow the changes in tone which occur in the base metal on exposure or weathering under interior or exterior conditions, as the case may be.

## FUSION WELDING BRASS AND BRONZE

*Oxidizing Flame Necessary.* All of these alloys are quite similar in exhibiting an unsatisfactory behavior when welding is attempted with a neutral blowpipe flame. In some of the brasses, the zinc distills off, forming heavy white clouds of zinc oxide when the alloys are melted; while with the alloys containing some lead, it is very difficult to attain a fluid condition of the base metal because lead melts out and covers the surface of the base metal making it difficult to melt the welding rod into it.

When bronzes high in tin or lead are heated certain constituents melt and exude from the metal at a temperature considerably below the melting point of the alloy.

All of these metals, both brasses and bronzes, boil when melted with a neutral flame. This condition is conducive to the development of gas inclusions so that porosity becomes a characteristic of the weld metal produced when these alloys are welded with a neutral flame.

By using a properly adjusted oxidizing flame instead of a neutral flame, the porosity of the deposited metal can be considerably reduced or entirely eliminated. Each type of alloy requires a slightly different flame adjustment. The procedures for determining the proper adjustment in each case are discussed in the following paragraphs.

*Flame Adjustment and Technique for Welding Brasses.* When welding brass, if the base metal is brought almost to the melting point by means of the neutral flame, it will be noticed that zinc fumes start coming off and that the surface of the metal is rather bright. If the flow of acetylene is then gradually reduced, or the flow of oxygen increased gradually, it will be noticed that at a certain point of excess oxygen flame adjustment a distinct coating is formed on the surface of the brass. The flame adjustment for this is quite strongly oxidizing. Avoid increasing the oxygen in the flame beyond this

point, as the coating or film would then become so very thick and refractory as to interfere with welding.

By using the oxidizing flame adjustment which just begins to produce the film, that is, when the coating just becomes visible, the boiling and fuming of the base metal will be practically eliminated; and this is the point at which the very best weld, free from porosity and of good tensile strength, is produced.

Due to the formation of the coating on the molten puddle, it is necessary to use a suitable flux whether any rod metal is being added or not. Both Oxweld Brazo Flux and Oxweld Cromaloy Flux are very satisfactory for this welding.

The flux is best applied by mixing with water to form a paste which is painted on the rod and on the base metal along the scarf.

Either forehand or backhand welding may be used, although as a general rule, forehand welding will produce more satisfactory results.

For welding the yellow brasses, Oxweld No. 25 M. Patented Bronze or Oxweld No. 21 High Strength Patented Bronze welding rods will produce weld metal having the same color as the base metal. In the case of a base metal of special composition or different color, however, welding rods consisting of strips of the base metal may be used very satisfactorily.

Always keep the surface well fluxed so that it will not be necessary to force the weld into the puddle. Do not overheat the metal or the rod, as this will cause fuming of the zinc in the alloy.

*Flame Adjustment and Technique for Welding Bronzes.* When fusion welding the bronzes which contain relatively high amounts of tin or lead, or both, it will be observed that these constituents start boiling out before the base metal is even at a red heat. By using a strongly excess oxygen flame, however, for both the preheating and the welding this tendency for tin and lead to boil out is eliminated.

After the base metal has melted and there is a noticeable film on the surface of the molten puddle, the amount of excess oxygen in the flame should be varied over a fairly wide range, during which it will be found that for one particular flame adjust-

ment the film or coating tends to disappear and a bright surface is maintained on the metal. This is the correct flame adjustment necessary for good welding of the high tin, high lead copper alloys. Usually a few preliminary trials will determine this adjustment, and once found, welds free from holes or gas inclusions and with well distributed tin and lead content can be made.

With alloys containing relatively large amounts of lead, say over 5 per cent, some difficulty may be encountered due to the excessive formation of lead oxide, but by the use of an abundant quantity of flux painted on the welding rod this will be largely eliminated. The same fluxes as for fusion welding of brass are found to be most satisfactory.

Fig. 114. Fusion welding a bronze gear. Observe local preheating.

Welding rod for these bronzes may be taken from the base metal itself, if an exact color match is desired. Oxweld No. 25 M. Bronze and Oxweld No. 21 High Strength Bronze welding rods are also suitable. Another rod found to be of exceptional value for color matching many of the bronzes used for castings is Oxweld No. 19 Cupro welding rod. As this rod is in the rolled form, it will produce higher quality weld metal than could be obtained from cast rods.

*Special Cases.* Very little difficulty should be encountered in the welding of rolled or extruded brasses or bronzes because almost any of these alloys that have previously been subjected

to hot work during forming have good strength under welding conditions.

There are a few complex casting alloys, however, which may require special care, particularly when welding restrained areas, because these alloys have very little resistance to hot work and to stress at high temperature. Proper preheating will, however, assist materially in relieving stresses in the base metal and this will permit the production of good sound welds.

The most satisfactory way to learn to weld these complex brass and bronze compositions is to obtain samples and experiment with different flame adjustments to determine the proper welding conditions.

The procedures which have been described are being applied with splendid results in welding many commercial brasses and bronzes, particularly those used for ornamental work.

In all of this work, due consideration must be given to joint design, and method of holding parts for welding.

In cases where a hair-line is not objectionable on the surface, welding can be done from the back. The two parts are clamped tightly together without veeing, a tack-weld is made at one end of the seam, and welding is started at the other end. This type of joint has the advantage of not requiring any finishing.

Where hollow sections are joined, as in the production of doors, window sashes and similar parts, welding must usually be done from the front. The edges of the seams are usually veed before clamping the assembly in position for welding. In order to simplify the finishing operations, the weld should be made with only a slight reinforcement, taking care to avoid any low spots. Wherever possible, attachments such as hinges, fasteners or ornaments on a frame should be welded to individual members of the frame before these are assembled into the rigid structure.

### BRONZE-WELDING BRASS AND BRONZE

As has been indicated previously, bronze-welding is widely used to produce perfectly satisfactory joints in most of the brasses and bronzes used for general industrial purposes. The majority of these alloys have melting points higher than that of bronze welding rod (about 1,650 deg. F.). With certain brasses, particularly yellow brass which has a melting range

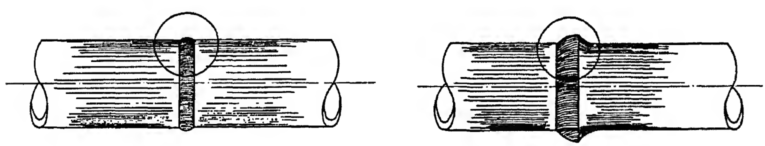
of 1,660 to 1,715 deg. F., the melting point of the base metal is so near that of the rod that the welding operation is a cross between bronze-welding and fusion welding. The welding of yellow brass is discussed in the section on welding brass pipe.

*Joint Design and Preparation.* Joint design and preparation for sheet, plate and castings is in general the same as for steel. Joint design for pipe is discussed in the section on brass pipe.

*Welding Technique.* The standard bronze-welding technique given in Chapter 18 should be followed in bronze-welding brass and bronze. This includes the use of forehand technique; Oxweld No. 25 M. Bronze Patented Welding Rod; Oxweld Brazo Flux; a slightly oxidizing flame; proper heat control; and careful tinning of the base metal ahead of the welding puddle.

## WELDING BRASS PIPE

*Composition and Sizes.* Commercial yellow brass pipe contains about 67 per cent copper and 33 per cent zinc, with small



Single vee butt type joint.

Bell-and-spigot joint for brass pipe of less than 1/8 in. wall thickness.

Fig. 115. Joint design for brass pipe.

traces of lead. It is supplied in a range of Iron Pipe Sizes, both in standard and extra heavy grades. Seamless drawn brass tubing with thin walls is also made in a range of plumber's sizes.

*Bronze-Welding.* The welding of commercial yellow brass pipe is easily accomplished by bronze-welding. Ample strength is assured by this method, as the tensile strength of weld metal deposited by the recommended welding rod (Oxweld No. 25 M. Bronze Patented Welding Rod) is 55,000 to 60,000 lb. per sq. in.

*Joint Design.* Joint design is in general the same as for steel pipe of corresponding size and wall thickness. For brass pipe where the wall thickness exceeds ⅛ in., the open single vee butt type with ends beveled to 45 deg. and with a $\frac{1}{16}$-in. unbeveled shoulder at the inside wall, is recommended, Fig. 115. For pipe having a thinner wall, the open square butt joint may be used or, in certain cases, the short-bell type joint (see Fig. 115).

Brass welding elbows are available in standard sizes.

*Welding Technique.* The welding of brass pipe calls for nothing unusual in pipe welding technique and can be easily done by any operator competent to weld steel pipe. Welding of yellow brass pipe of this composition, in which the melting point of the base metal so closely approximates the melting point of the bronze welding rod, is really a cross between fusion welding and bronze-welding. The essential factor is to melt the wall of the vee just sufficiently to insure positive sweating of the base metal in advance of the puddle. Oxweld No. 25 M. Bronze Patented Welding Rod and Oxweld Brazo Flux should be used.

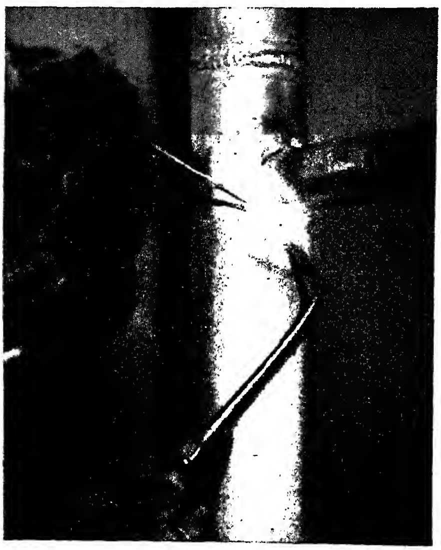


Fig. 116. Welding a 2-in. branch connection in 4-in. brass pipe.

Rotation welds offer no difficulty whatsoever, requiring only a little longer time to start welding because of the higher heat conductivity of brass as compared to steel. Puddling and manipulation of rod and flame are the same as in steel welding with forehand technique. Overhead welding likewise is easy and not at all complicated. The welding, as for steel pipe, merely requires the proper manipulation of rod and flame in controlling the puddle.

Welding brass pipe in a fixed vertical position is less easily accomplished, as is true with steel pipe, but here likewise any operator competent to weld steel pipe in this position can control and deposit the bronze weld metal with ease. A suitable technique is to deposit the metal in a sloping puddle, directing the flame upward so as to retain the molten metal, at the same time manipulating the rod in the puddle to prevent excessive melting of the upper half of the joint and to solidify the puddle in even ripples. This again is similar to ordinary steel pipe welding technique.

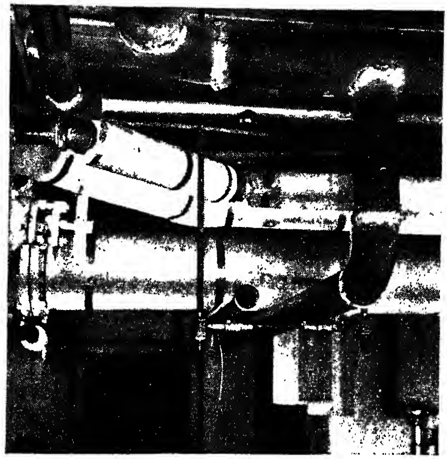


Fig. 117. Typical installation of welded brass piping. Observe use of welding elbows.

As this brass contains a small amount of lead, there is a tendency for the base metal to honeycomb slightly at the edge of the weld, but this is only a surface factor and is unimportant.

The welding should be done with a slightly oxidizing flame, since a drift of the flame to a reducing adjustment (excess acetylene) would cause excessive boiling.

*Time and Materials.* A comparative study of welding rates and material consumption for welding brass and steel pipe has shown that a conservative estimate may be made on the basis that the welding time and oxygen and acetylene required for welding brass pipe are about 15 per cent less than for steel pipe where forehand technique is employed, the rod consumption being practically the same.

*Tensile Test Data.* Results of tensile tests of coupons cut from bronze-welded joints made in various positions in 4-in. standard I.P.S. (iron pipe size) brass pipe are given in Table II. It will be noted that the strength of the annealed brass pipe, approximately 32,000 to 42,000 lb. per sq. in., was obtained in all the tests.

## TABLE II

## TENSILE TEST RESULTS

Coupons Cut from Butt Type Joints in 4-in. Std. I.P.S. Brass Pipe

| Weld No. | Type of Weld | Welding Time Min. | Tensile Strength of Coupons Lb. per Sq. In. | Fracture * |
|---|---|---|---|---|
| A | Rotation ....... | 9½ | 38,200 | Weld and pipe |
| | | | 35,100 | Weld and pipe along scarf |
| B | Rotation ....... | 8 | 35,800 | Weld and pipe near scarf |
| | | | 34,100 | Weld and pipe near scarf |
| C | Rotation ....... | 12 | 42,000 | Base metal ¾ in. from weld |
| D | Vertical Position | 8½ | 35,400 | Base metal and scarf |
| | | | 39,300 | Base metal |
| | | | 32,500 | Base metal near scarf |
| | | | 39,000 | Base metal |
| | | | 34,000 | Base metal near scarf |
| | | | 37,600 | Base metal near scarf |
| E | Horizontal Position | 12 | 32,000 | Along scarf, small lap |
| | | | 32,100 | Base metal near scarf |
| | | | 33,600 | Base metal near scarf |
| | | | 35,300 | Base metal near scarf |

* Most of the specimens failed in the base metal near the scarf, but this is believed to be due to stress influence set up at this point by the stronger and harder weld metal when the softer base metal started necking down at the point of failure.

CHAPTER 26

# Welding Nickel and Monel Metal

GENERAL *Properties.* So far as welding is concerned, nickel, Monel metal and certain other high nickel alloys can be considered as a group.

Commercial nickel is the commercially pure metal, containing over 99 per cent nickel. Monel metal is a high nickel-copper alloy containing 65 to 70 per cent nickel, 26 to 30 per cent copper, with small amounts of iron, manganese, silicon and carbon.

Because of their resistance to many corrosive materials the high nickel alloys are widely used in the chemical and food products industries. Monel metal is resistant to both acid and alkaline corrosion. It is used for a wide variety of chemical process equipment, laundry machinery, dry cleaning equipment, hotel equipment and for many similar purposes. Nickel, while slightly less resistant to acids, is very resistant to alkalis and to a wide range of salts. A typical use for nickel in the chemical industry is in the construction of evaporators for caustic soda and various food products. Other standard items in the food industry made of nickel are steam jacketed kettles, and brine and syrup tanks.

The welding of these high nickel alloys requires a somewhat special technique as their behavior under the blowpipe flame differs considerably from that of most other non-ferrous metals. These high nickel alloys contain small amounts of certain deoxidizing elements, and these essential elements must not be allowed to boil out during welding as otherwise the hot metal will absorb gases and the result will be a porous weld.

Another peculiarity of these high nickel alloys that must be taken into consideration in welding is the fact that they have a "hot short" range—a range of low tensile strength and brittleness—between the temperatures of 1,450 to 1,650 deg. F.

Both above and below this "hot short" range they regain their normal strength and ductility. It is consequently important to control expansion and contraction during welding so that no undue stresses will be present while the weld metal and the adjacent base metal are passing through the hot short range as the weld cools. Cooling parts should not be held rigidly but should be allowed to contract naturally.

*Joint Design.* Joint design and preparation for sheet, plate, tubing or castings are essentially the same as for steel of similar form and thickness. For thin gauge metal the flange type joint is particularly recommended and the bottom and top of the seam should be painted with a paste of flux.

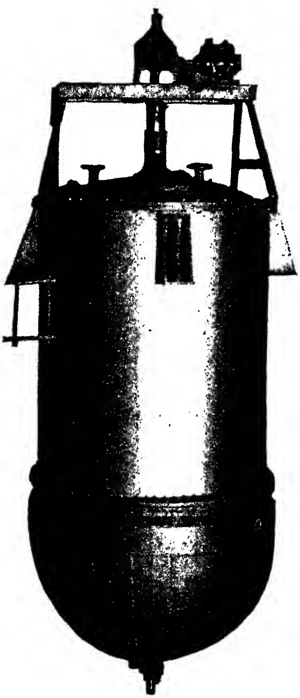


Fig. 118. Oxwelded nickel mixing kettle with oxwelded steel jacket at base.

*Use of Jigs.* Partly because of the hot-shortness of the high nickel alloy, more attention should be given to the proper design of jigs and fixtures than is necessary when welding steel.

A simple jig for welding long seams consists of a piece of 3/16 in. steel plate, 8 to 10 in. wide and as long as the seam, with a shallow lengthwise central groove; two pieces of angle iron, one for each top side of the seam; and four C-clamps. The C-clamps insure metal-to-metal contact between jig and sheet. The jig thus acts as a chill, absorbing heat that would otherwise work out into the sheet and cause distortion. In some cases copper bars are used so as to insure maximum heat absorption. The groove in the bottom plate of the jig is placed directly under the seam. It permits more rapid welding and insures that the bottom edges of the sheet are thoroughly fused. In jigs for making corner welds, the sharp corner of the inside jig angle is filed away slightly, for the same reason.

*Welding Methods.* Nickel and Monel metal can be fusion

welded with welding rod of composition similar to that of the base metal. The high nickel alloys can also be bronze-welded and in some cases they are silver soldered using the oxy-acetylene flame as described in Chapter 33.

## FUSION WELDING NICKEL AND MONEL METAL

*Welding Rod.* For fusion welding nickel and Monel metal, it is advisable to use welding rod of the same composition as the base metal. This is necessary because the service conditions under which these metals are used usually require that the base metal and weld metal have comparable corrosion resistance. Rod to be used for welding should always be so specified in ordering from the manufacturer. Where it is not possible to obtain welding rod, strips cut from the base metal can be used.

*Flux.* In welding the high nickel alloys, the use of a suitable flux is necessary to assist in the removal of oxides and to improve the fluidity of the weld metal. Oxweld Brazo Flux is recommended. The flux may be used either as a dry powder into which the heated end of the welding rod is dipped or as a thin water paste which is painted on the seam with a small brush and may also be applied to the welding rod.

Welding heads or tips for nickel or Monel metal welding should be about one size larger than for the corresponding thickness of steel. Because of the tendency of certain elements in the base metal to oxidize, the flame should be adjusted so as to have a slight excess of acetylene. The flame should also be soft rather than harsh. The outer envelope of the flame should cover the weld during the whole operation so as to keep the molten metal from being exposed to the air and consequent oxidation. It is also advisable to keep the end of the welding rod well within the flame during welding.

Backhand technique with the flame pointing toward the completed weld is recommended as it slows up contraction during cooling and lessens oxidation.

There should be little puddling of the weld metal; the molten metal should be kept quiet, with the tip of the inner cone just touching its surface. Puddling tends to burn out the deoxidizing elements, the essential ingredients of the high nickel alloys which must be retained to aid in assuring sound weld metal.

Inasmuch as such oxides as are formed during welding will

float to the surface of the weld, it is recommended that the weld be reinforced sufficiently to allow for grinding after completion. This will remove all of the oxide slag and will give the finished weld a neat appearance.

In welding nickel or Monel metal sheet, the welding should proceed continuously and rapidly to the end of the seam without lifting the blowpipe from the work. Any distortion in the welded sheet can be easily removed by hammering or rolling as the weld is soft and ductile.

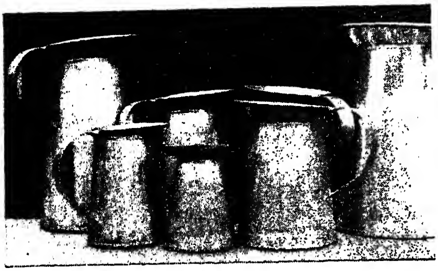


Fig. 119. Welded Monel metal dye measuring cans used by textile industry.

In welding nickel and Monel metal of plate thickness, the sides of the vee should be preheated to a red heat for a short distance ahead of the starting point. Fuse the sides and bottom of the vee simultaneously. Then preheat the end of the welding rod and allow it to melt underneath the surface of the molten puddle without agitation. For very heavy material the joint should be welded in sections. Each section, about 2 in. long, should be completed including reinforcement before starting the next one. When welding a double vee the second weld should not be made until the whole piece has been reheated to a dull red.

### WELDING NICKEL AND MONEL METAL CASTINGS

While nickel and Monel metal castings are welded with the same technique as other forms of these metals, their physical properties make it necessary to give special consideration to preheating and annealing.

High nickel castings resemble cast iron in that rapid cooling will set up severe internal strains. Because of their "hot shortness" they also resemble aluminum castings in that they must be adequately supported when hot. Very light sections should be supported by carbon blocks. Castings of varying cross-sections should be so lined up as to distribute the weight equally and to provide for even heating.

*Preheating.* Nickel and Monel metal castings should always be preheated before welding. For very small castings the welding blowpipe may be used but for larger ones the work should be done in a preheating furnace capable of slow and even heating. The casting should be brought slowly and evenly to a dull red heat, about 1,200 deg. F. This temperature should be maintained as steady as possible during welding.

*Annealing.* When the weld is completed the casting should be reheated until an even temperature is secured throughout. It should then be cooled slowly and evenly in the furnace or in an annealing bin.

## SUPPLEMENTARY READING

Additional information on the properties and uses of nickel, Monel metal and other high nickel alloys can be obtained from the International Nickel Company, New York City.

CHAPTER 27

# Welding Lead

THROUGH trade custom, the fusion welding of lead is customarily referred to as "lead burning." Strictly speaking, this term is quite incorrect, as the lead is not burned at all and the operation produces a true fusion weld entirely analogous to welds made in other metals, such as steel.

Being a true welding operation, lead welding can be done most satisfactorily with oxy-acetylene welding equipment. Because of the low melting point of lead, only a very small flame is required and it is consequently possible to use a special blowpipe. Operators will experience little difficulty in learning how to work with lead. To be sure, the technique is somewhat different from that required for steel, but the difference is hardly any greater than between steel and aluminum, for example. In many plants, particularly paper mills where lead is used extensively, the welding shop is expected to handle all lead work just as it would any other metal.

## PROPERTIES OF LEAD

Pure lead is a heavy, soft metal, dull gray in surface appearance, but exhibiting a bright metallic lustre on a freshly cut or scraped surface. It has very little mechanical strength and consequently care must be taken to support all large pieces or they will collapse under their own weight.

Where greater strength is required, lead containing antimony is used. The greater hardness of this antimonial or chemical lead is at once evident when an attempt is made to scrape the surface. The freshly scraped surface of antimonial lead has a silvery appearance compared with the bluish tinge of pure lead.

The dull gray surface appearance of lead is due to a coating of oxides and other compounds that must be carefully removed before welding. For preparing the edges and surface of

lead, special tools known as "scrapers" are available. The metal is so soft that the preparation of pieces for welding is a relatively simple matter. The main point is to clean the surface so that thorough fusion will result.

As far as actual welding is concerned, the most important property of lead is its low melting point. This means of course that only a very small flame is required. In fact lead melts so easily even with a small flame that the technique of blowpipe manipulation is quite different from that used with any other metal. Best results are obtained with a flame containing a slight excess of acetylene.

Holding the blowpipe so that the flame is almost perpendicular to the surface of the work, and with the inner cone almost touching the surface of the metal, heat the lead until it just melts, then lift the blowpipe quickly in order to prevent excess melting. This will require considerable practice until the operator learns to recognize the exact point of fusion. Lead welding is a delicate operation. The blowpipe flame is directed on the metal for an instant and quickly flipped away. In this way it is possible to control this easily fused metal. Light lead sheet with flanged edges may be welded without the addition of rod, but for most work additional metal is required.

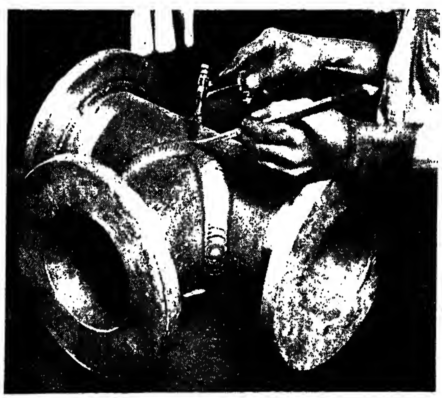


Fig. 120. Position for welding lead.

The welding rod, or "burning stick" as it is usually called, may be made by cutting sheet lead into strips, or by melting some lead and molding it into rods of convenient size. Where much work is done, special molds can be obtained. Probably the simplest method is to use a short length of angle iron, melting the lead into the vee of the angle by means of the blowpipe, thus forming a bar of any desired size.

In adding metal from the rod, the blowpipe flame should be played simultaneously on the rod and along the edges of the work to be welded so that they will reach the fusion point at the same time. Thorough fusion is just as essential in lead welding as it is in welding steel. While high strength is obviously not a factor in lead welding, the welds must be perfectly tight, and this is, of course, not possible without thorough fusion.

### WELDING SHEET LEAD

In most work with sheet lead, such as tank linings, lap joints are used. The sheets are laid out with edges overlapping from ¼ to ½ in. The overlapping surfaces of both sheets must be thoroughly cleaned in addition to the exposed edges of the

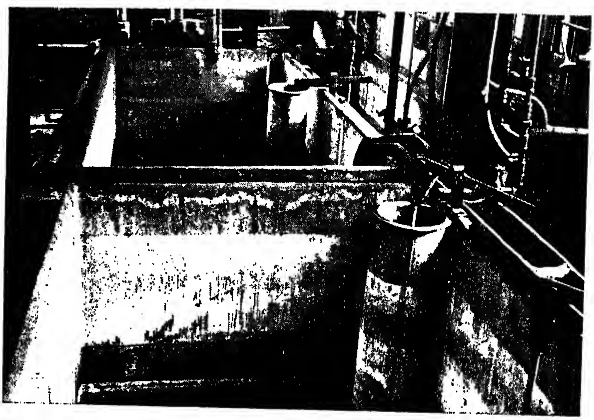


Fig. 121. Lead-lined tanks.

sheets. Usually forms must be used to support the sheet as the metal is too soft to remain in position unsupported. After the lap joint is in position, the joint should be tapped lightly with a wooden mallet in order to bring the sheets in close contact. Each edge of the lap is then welded, using rod.

Where it is not possible to work from both sides, as for example when a lining must be made in place, the butt weld is preferable. The sheets are carefully trimmed to size and the edges beveled just as in working with steel. The sheets are supported in position and then tack-welded to maintain align-

ment. Any shaping that may be necessary in lining up the sheets can be easily done with a wooden mallet.

Vertical seams should be started at the bottom, the work progressing upward.

### LEAD PIPE AND FITTINGS

Lead pipe is obtainable in a variety of sizes and weights, and welded joints may be made by following the same general methods of design that are used in welding steel pipe.

Specials of lead pipe may be made very easily from sheet lead by cutting to size, shaping around a wooden or metal form, and then welding the longitudinal seam.

Flanged joints are used quite extensively in lead pipe work in industrial plants, particularly in the chemical and paper industries. Many of the plants make their own flanges. The flange is molded so as to slip over the outside of the pipe, and has a bevel on the inside edge of the ring so that it can easily be welded to the end of the pipe.

Fig. 122. Welded lead piping handles corrosive chemicals.

Fittings of all types can be made much more quickly than corresponding fittings in steel pipe. Due to the low melting point of the lead, holes for branch connections are made by simply melting through the pipe wall with the lead welding blowpipe flame. Thus the welding blowpipe also assumes the functions of the cutting blowpipe. The melted edges are, of course, scraped clean and properly shaped before welding. Owing to the softness of the metal, the parts may be made to fit exactly with very little effort. Fig. 120 is a splendid example of the results that may be obtained with careful workmanship. This flanged tee was made entirely with the oxy-acetylene welding blowpipe. Flanges were welded on, the hole was melted for the branch, and then

the branch was welded in. In metal of this thickness, welding may be done in two stages. The vee is first welded almost level with the surface; and the joint is then finished, using a rather different blowpipe movement which produces the characteristic over-lapping ripples.

## STORAGE BATTERY WORK

It is extremely difficult to weld lead which has been subjected to the action of a strong acid, such as the sulphuric acid used in storage batteries. Where it is possible to neutralize the acid by a solution of ammonia or sodium bicarbonate without getting any into the battery and injuring it, that method is allowable. It is decidedly better in all cases, however, to wipe dry the parts to be burned and then scrape them bright. The scraping will remove the layer of lead which has been affected by the acid and will insure a good joint.

*Burning Plates to Plate Connectors.* Set up the plates in a burning rack or comb, which will provide for proper spacing and true alignment. The lugs of the plates must extend above the top of the comb. Place the post in position before attempting to burn the lugs together on a lead strap. To burn, play the flame along the ends of the lugs, and when they are molten, add metal from the burning stick and form a strap connecting them all and the post. A comparatively large flame should be used to insure perfect joints because the plates must be fused perfectly to the strap and post.

If a slotted plate strap or connector is used, set up the plates as described above with the lugs extending up into the slots. To burn, play the flame along the sides of the slots to bring them and the lugs to a melting point at the same time, then add metal from the burning stick to fill up the slots, and finish the strap off smooth.

*Burning Cell Connectors or Terminals to Terminal Posts.* The connectors should be tapped lightly with a small wooden mallet until they fit snugly around the terminal posts. To secure a good burn, it is necessary that the surface of the top of the terminal post be about 1/4 in. below the top surface of the cell connector or battery terminal. If necessary, the post should be cut off to insure this feature. To burn, play the flame on the top of the post and bring it and the inner wall of the

connector to a molten state, forming a molten pool. To this add metal from the lead burning stick. As the pool fills up, be sure to watch that the metal on the inside wall of the connector flows into and with the added metal. Continue until the added metal is flush with the top surface of the connector. Then allow the connector or terminal to cool sufficiently so that the lead will not crumble when brushed, clean the top with a wire brush, and again apply the flame and add enough lead to smooth off and finish the job.

Fig. 123. Welding a storage battery terminal connection

It is sometimes impossible to burn on a connector or terminal in one complete operation, because the metal surrounding the cavity becomes overheated. In such cases, stop work as often as the lead seems to be running too rapidly, and allow it to cool before proceeding.

In burning on a terminal in which the end of a cable is imbedded, protect the rubber insulation on the cable with a strip of wet cloth, to avoid burning it.

In battery repair shops it is often necessary to build up a terminal post which was drilled out when the battery was torn down. When building up a post, a mold should be used to hold the metal in place. This mold can be made of sheet metal and should be tapered so as to be easily withdrawn from the finished work. Be sure that the top of the post is in a molten state before adding lead, so that the post and the metal added will be solidly fused. Unless this is done, the joint is very likely to be weak.

## CHAPTER 28

# Testing Welds

METHODS for testing welds may be divided into two general groups: destructive and non-destructive.

Tests of the first type may involve destruction of a complete welded unit or may require specimens cut from a unit that has been selected as representative of the entire lot. Destructive tests are also extensively used in determining the ability of operators. Routine destructive tests include fracture test, tensile test, and bend test.* In addition, there are tests which are used mainly in research investigations, such as fatigue tests, Izod or other notch impact test for shock resistance and the hardness survey.

For the majority of welded products, however, it is desirable to have some method of routine testing that can be applied to every individual unit. In recent years much thought has been given to this subject, and a number of non-destructive routine tests have been developed.

Tanks, closed containers, pressure vessels of all types, pipe lines and piping systems, where absolute tightness of all joints is essential, are tested by the application of internal pressure. This affords a most convenient means of determining the soundness of welds. Wherever possible, hydrostatic pressure should be used for making pressure tests. It is preferred because, in case of sudden release of pressure, there is little tendency for parts to be thrown about violently.

### HYDROSTATIC PRESSURE TESTS

The equipment for hydrostatic pressure testing consists of a pump, a pressure gauge, and the necessary piping connections. Suitable pumps are relatively small in size and convenient to

* For a complete discussion of these tests see "The Testing and Qualification of Operators of Welding Equipment", published by The Linde Air Products Company.

use. Pressures up to 6,000 lb. per sq. in. can be easily obtained. The vessel is first completely filled with water, and all air bubbles are allowed to escape so that there will be no air pockets. After all outlets to the vessel have been closed, the pump is operated until the desired pressure is obtained. This is usually at least one and a half times the normal working pressure. See Fig. 124.

In the case of pressure vessels, specifications may call for a hammer test while the vessel is under a pressure of twice the designed working pressure. The weight of the hammer in pounds is equal to the shell thickness in tenths of an inch, and the blows should be struck at 6 in. intervals on both sides of the weld for the full length of the seam. This is followed with a thorough visual inspection. The hydrostatic pressure is then raised to three times the designed working pressure and the seam again inspected. This pressure impact method is used as a means of testing the strength and soundness of welds for high pressure service.

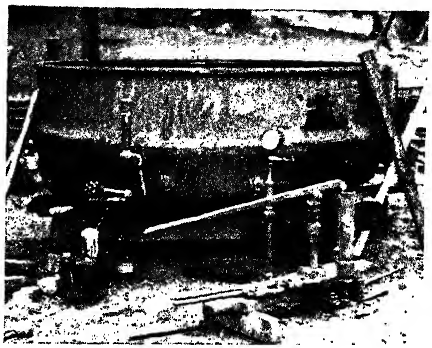


Fig. 124. Oxwelded steam-jacketed kettle ready for hydrostatic pressure test.

## AIR PRESSURE TEST

For certain types of work, it may be inconvenient to use hydrostatic pressure for testing. In the case of pipe lines for oil and gas, for example, it would be difficult to obtain the required amount of water to fill the line. Furthermore there would be difficulty in draining out the water after the test was completed. A section of the line is blanked off by means of bull plugs, or other suitable closures, and after attaching pressure gauges, compressors are placed in operation until the required test pressure is built up in the line. Each weld is then painted with soapy water and carefully inspected for bubbles, which would indicate pin hole leaks. Test specifica-

tions may also require that each weld be hammered vigorously while under pressure, and then be tested again with soapy water. Gas lines are frequently required to hold the pressure over a period of time, recording pressure gauges being attached to the line to register changes in pressure. In noting the result, due allowance must be made for any temperature fluctuations that may have occurred during the test period.

## TESTING LOW PRESSURE TANKS

The testing of low pressure tanks, particularly the aluminum fuel tanks used in aircraft, is usually done by means of air pressure. These tanks are tested with 4 to 5 lb. per sq. in. in pressure. The welds may be painted with soapy water, or the entire tank submerged in a large vat of water to locate any possible pin hole leaks. See Fig. 125.

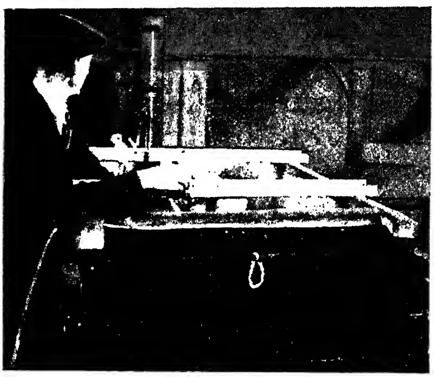


Fig. 125. Aluminum tank undergoing air pressure test while completely submerged in large vat of water.

## REHEATING OF WELDS

For light-gauge sheet metal products which cannot be subjected to pressure tests a non-destructive test may be carried out with the blowpipe. Using a fairly large head on the blowpipe the inspector heats the entire length of the seam gradually and evenly to a medium heat. As the weld is thicker than the adjacent sheet metal, it does not heat up as readily as the sheet. A perfect weld will show as a uniform unbroken darker strip in the heated area. The presence of any defective places due to incomplete penetration, blowholes, cold shuts or laps will be indicated by bright spots in the relatively darker weld area. Where thorough fusion has not been obtained between the base metal and the weld metal, these sections will also show up bright while the rest of the weld will remain dark. Any

defective spots are returned to the welder for rewelding. This method has shown by experience to be rapid, accurate and economical in the testing of welds in sheet metal. See Fig. 126.

Fig. 126. Inspector testing sheet metal product by reheating the welds with the blowpipe.

STETHOSCOPE TEST

It is known that the presence of a serious defect in a vessel can often be determined by its ring. This method was used by the village blacksmith when he hammered metal cold on the anvil, to test it by its sound. In sounding a tank, however, there are a great many difficulties to be encountered due to the forced and natural vibration of the tank and the tendency for the natural vibration to drown out all other sounds.

In a modern adaptation of this method, the weld area is struck with a hammer and the sound is amplified by the use of a physician's stethoscope equipped with a gum rubber tip to exclude extraneous sounds. It is possible to distinguish between the characteristic sounds produced by a sound weld and by one that has even minor defects. This method has been applied to welds in pipe, pressure vessels, plate and structural steel. See Fig. 127.

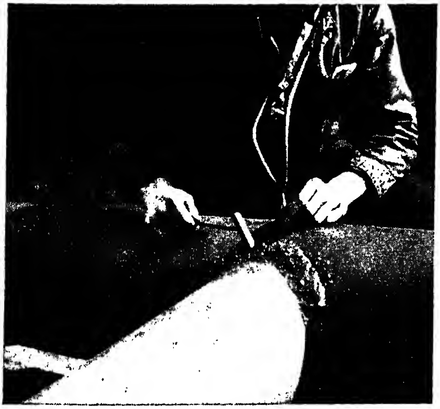


Fig. 127. Testing welded pressure piping with stethoscope.

## X-RAY AND MAGNETIC TESTS

Quite recently technique and equipment for X-ray testing of welded products have been developed to a point where this method is being applied in the routine testing of large and important welded pressure vessels and other similar products upon which it can be used to advantage.

Another method that is being used quite extensively is based upon an examination of the effects produced when a magnetic flux is passed through the weld and adjacent base metal.

CHAPTER 29

# Rebuilding Worn Parts

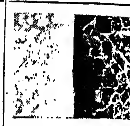
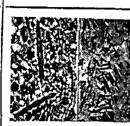
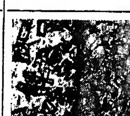
SCOPE. Oxy-acetylene welding affords an ideal method for building-up metal surfaces that are worn or abraded because the added metal can be selected so as to give exactly the right properties or degree of wear resistance required for each specific type of application.

There are six general types of rebuilding operations. The choice for a specific job depends upon the service conditions under which the part operates and upon the wear resistance desired in the rebuilt part. Depending upon the type of welding rod or material selected for the surfacing operation, the rebuilt part can be made to have the same properties as the original part or its resistance to wear and abrasion can be made much greater than that of the original.

Essential facts regarding these six general methods are given in the accompanying chart.

Method 1, bronze-surfacing, is discussed more fully in Chapter 30; while Methods 4 to 6 are treated in Chapter 31, Hard-Facing. Methods 2 and 3 are self-explanatory from the chart and require no further discussion as the method of application involves simply the normal fusion welding technique.

# REBUILDING WORN PARTS BY

| | OPERATION | PURPOSE BEHIND USE OF OPERATION | METALS TO WHICH OPERATION IS APPLIED | TYPE OF SURFACE RESULTING | TYPE OF BOND• |
|---|---|---|---|---|---|
| 1 | Bronze-surfacing with a rod such as the new wear-resisting bronze rod.* | For building-up worn surfaces. Low melting point rod for ease of application and easy machining. For wearing surfaces in lubricated places or non-lubricated places where low heat conditions prevail. | Cast iron, alloy and semi-steel, carbon steels, alloy steels, malleable iron, wrought iron, copper base alloys, Monel metal, nickel. | Surface can be easily machined to close tolerance. |  Bronze-weld metal (left); cast iron (right). |
| 2 | Re-surfacing with rod of composition same as or very similar to base metal, such as High Test steel welding rod.** | To restore part to original condition and size. | All metals ordinarily fusion-welded and heat-treated alloys that can be given subsequent heat-treatment to restore original physical properties. | Can be machined with same facility as base metal. |  High Test steel weld metal (left); mild steel (right). |
| 3 | Re-surfacing with rod similar to but not same as base metal, such as an alloy steel rod with air-hardening properties. | To restore a worn part to original size and give a deposit that may be subsequently forged, heat-treated, or left as welded in a condition superior to original in hardnessandtoughness. | Carbon steels, wrought iron, low alloy steels Note: Should not be applied to heat-treated steels except in special cases. | Usually not easily machined, but can be easily ground, forged or heat-treated. |  Air-hardening steel (left); 0.70% carbon steel (right) |
| 4 | Hard-surfacing with iron base wear-resistant alloys (chromium-manganese-iron).† | For parts subjected to moderate abrasive wear or severe impact. Have greater hardness and wear resistance than (3) and are often used as filling or base materials under the more wear-resistant non-ferrous alloys (5) and (6). | Carbon steels; low alloy steels though in some cases heat-treatment after application may be necessary. Alloy and semi-steel castings: gray cast iron. | Can be ground to close tolerance. Can be forged or heat-treated if necessary. |  Hascrome (left); steel (right). |
| 5 | Hard-surfacing with non-ferrous wear-resistant alloys (cobalt-chromium-tungsten).†† | For resistance to severe abrasion and especially for resistance to abrasion at elevated temperatures as the hardness of these alloys is retained at a red heat. | Same as (4). Also Monel metal and high chromium (stainless) steels. | Grinding finish to very close tolerance. No forging possible and unaffected by heat-treatment. Cannot be machined. |  Haynes Stellite (left); steel (right). |
| 6 | Hard-setting and hard-surfacing with diamond substitutes (inserts of tungsten carbide)‡ or a composite rod consisting of crushed particles of tungsten-carbide in a bonding material.‡‡ | For parts subjected to extremely severe abrasion. | Carbon steels (heat-treatment often necessary) Low alloy steels (heat-treatment often necessary). Alloy, semi-steel, gray iron castings. | Surface used as originally applied. |  Haystellite (left): steel binder (right). |

*Oxweld No. 25 M. Patented Bronze Rod.
**Oxweld No. 1 H. T. (High Test) Patented Steel Rod.
†Hascrome Welding Rod.
††Haynes Stellite alloy.
‡Haystellite Inserts.
‡‡Haystellite Composite Rod.
•All photomicrographs X50.

# THE OXY-ACETYLENE PROCESS

| PREHEAT AND ANNEAL | FLAME ADJUSTMENT | HEAT CONTROL | OTHER ESSENTIAL TECHNIQUE POINTS | TYPICAL EXAMPLES |
|---|---|---|---|---|
| Normally not necessary. Only used to prevent heat effect of flame such as warping or cracking when large surface is to be rebuilt. | Slightly oxidizing. | Base metal should be heated by flame only to the point where molten fluxed rod flows over the base metal like water over a wet surface, i.e., a "sweating" heat. | A flux prepared specially for bronze-welding should be plentifully used. | Pistons, sliding valves, seal rings and other wearing reciprocating parts used dry at low temperatures or hot and well lubricated. Other typical parts: rocker arm rollers, lever bearings, gear teeth, shafts, spindles, yokes, pins and clevises. |
| Usually unnecessary May be advisable to counteract heat effects when building-up large surface area. | Same as fusion-welding adjustment for particular base metal under consideration. | Same as for joining two parts together. Do not overheat unnecessarily. | Follow welding technique used for joining the material. | Many badly worn parts are rebuilt with rod of same composition preparatory to hard-surfacing. This for economy's sake. |
| Generally unnecessary on carbon steels and wrought iron. A blowpipe treatment advisable where base metal depends on heat-treatment for its properties. | Neutral, unless it is desired to spot harden by increasing carbon content of the deposit, in which case more or less reducing adjustment should be used. | Same as for joining two parts by fusion welding. Do not overheat. | No flux used except on certain chromium steels where Cromaloy flux is essential to success. | Rail ends, dies, rolls, anvils, etc. |
| Ordinarily unnecessary for carbon steels unless large area is to be covered Preheat and anneal advisable for casting and essential on alloy steels. When necessary, quench in oil—not water. | A very slightly reducing flame. Do not use a neutral flame adjustment. The hardness of the deposit is affected by the amount of excess acetylene. | Heat base metal to "sweating" temperature so rod flows over heated area. Do not mix base metal and rod in a molten puddle. Slight puddling is necessary on cast iron. | A good flux may facilitate the work on cast materials but is unnecessary otherwise. | Gyratory crusher mantles, crusher jaws, dipper teeth, etc. |
| Ordinarily unnecessary for carbon steels up to 0.60 per cent carbon or on Monel metal. Preheat and anneal advisable for castings and certain high chromium steels. When necessary, quench in oil—not water. | Excess acetylene (carburizing) flame. Acetylene feather double the length of inner cone. On cast iron use a little less excess. | Heat base metal to "sweating" temperature so rod flows over small heated areas. Do not mix base metal and rod in a molten puddle. Cast iron requires very slight puddling. | Flux unnecessary though may facilitate work on cast iron. Base metal should be well cleaned of dirt and scale. | Steam valves and valve seats, gasoline and diesel engine valves and exhaust valve seats, dies, plow shares, hot shearing knives, coke pusher shoes, grizzlies and many other parts subjected to severe abrasion or to heat and abrasion. |
| Usually advisable because most base materials on which diamond substitutes are applied have been hardened. | Very slightly reducing | As the bonding agent is usually one of the aforementioned materials (2) (3) (4) (5), use same technique and heat control. It is important to keep heat always at a minimum. | No flux necessary or advisable. Inserts should be ⅓ submerged in base metal and then entirely covered with bonding material. | Oil well drilling tools, coal undercutter bits, dredge cutters, airplane tail skids, etc. |

CHAPTER 30

# Bronze-Surfacing

AS indicated in Chapter 18, bronze-surfacing is a specialized application of bronze-welding which has as its objective the building-up of worn parts which are subject to sliding friction in service. It is widely used for rebuilding pistons, bull rings, rotary valves, guides, and other sliding surfaces on pumps, engine and machinery parts. By the application of wear-resisting bronze-welding rod to the worn surface and subsequent machining to original size, the part is made new again with even greater efficiency than it had originally. This results from the fact that bronze is an ideal material for services involving sliding friction.

*Advantages.* The advantages of bronze-surfacing are well emphasized in the case of pistons. When pistons become worn, the efficiency of the machine in which they operate is reduced. Eventually a point is reached where formerly it was necessary to scrap the worn piston or install a smaller diameter cylinder liner. As either procedure was costly, the operation was put off as long as possible with the result that the machine would operate for some time at reduced efficiency.

Fig. 128. Bronze-surfacing a large piston.

As bronze-surfacing is much less expensive and is easily done, a piston can be rebuilt before its efficiency has been materially reduced. The net results of the use of bronze-surfacing are thus lower operating costs, greater efficiency of operation and longer life with less wear on the pistons because of proper clearance.

*Characteristics Affecting Certain Applications.* There are two characteristics which must be understood, as they affect certain applications of bronze-surfacing.

One of these is the effect of high temperature on the physical properties of bronze. Bronze begins to lose its strength at temperatures above 500 deg. F. For this reason, bronze-surfacing should not usually be applied to surfaces exposed to operating temperatures higher than 500 deg. F. Temperatures higher than this are found in industrial reciprocating equipment only in exceptional cases and, therefore, this is not a serious practical limitation. Measurement of temperatures on diesel pistons has shown that although temperatures at the crown may be slightly in excess of 500 deg. F., the temperature of the piston walls is not generally over 300 to 400 deg. F. even close to the crown. Bronze-surfacing for steam engines operating at 250 lb. per sq. in. gauge pressure, equivalent to temperatures of 400 deg. F. or slightly higher have given excellent service.

Fig. 129. Bronze-surfacing an automobile clutch part.

The other characteristic affects certain applications of the bronze-surfacing of steel. This has been observed in cases where it has been necessary to reapply bronze-weld metal a number of times on steel wearing surfaces which are subjected to severe alternating and repeated stresses. Under such conditions, there is a possibility that bronze weld metal may, on repeated application, penetrate between the grains of the steel base metal to an extent which may cause cracking of the steel. It is, therefore, the recommendation of experienced welding engineers that bronze-welding should be applied only once on steel parts subjected to severe alternating tension and compression stresses. It is important to emphasize that this penetration occurs in steel only under the stress conditions

described and that it does not occur when bronze-welding is applied to cast iron. Consequently, bronze can be applied and reapplied as often as desired to cast iron.

*Preparation for Bronze-Surfacing.* The surface that is to be rebuilt must, if new or if showing but little wear, be machined

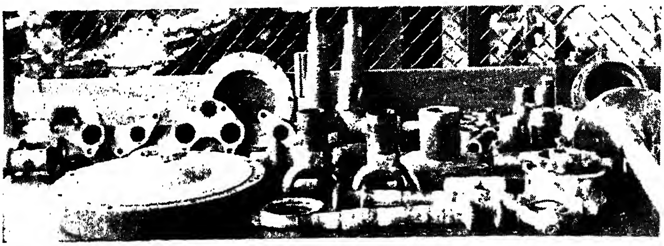


Fig. 130. Automobile parts reclaimed by bronze-surfacing.

or ground down sufficiently so that a layer of bronze can be applied. Surfaces that are worn will probably not need this preliminary work. Knowing that the bronze-layer, provided it has been properly bonded, can be machined down to the almost infinitesimal thinness, and knowing that the operator can limit the thickness of the bronze layer to at least ⅛ in. and often less it is a simple matter to calculate to what extent preliminary machining, if any, will be necessary.

Obviously those parts which do not require close finish tolerances very often can be permitted to wear to the point where no preliminary machining is necessary before the rebuilding operation. For this work a good cleaning of the surface to be rebuilt is all the preliminary preparation required. The bronze is then applied to the requisite thickness, allowing, of course, enough of a layer to permit final machining of the part.

Machining is not recommended when preparing cast iron surfaces because this operation tends to spread or smear the graphite particles over the surface in a way that interferes with tinning. Heating to a dull red will remove this surface graphite, but it is simpler to chip, grind, or sand-blast the cast iron surface.

*Important Precaution.* If the work is to be done on a hollow piston head, the core plugs must be removed or a hole drilled

into the cavities before welding in order to prevent the trapped gases from expanding and bursting the piston head.

*Preheating.* As in the case of all bronze-welding it is advisable to remove the chill of cold metal before bronze-surfacing. Whether this can be done with the blowpipe, or whether preheating will be required, is determined largely by the size, shape, and complexity of the part to be bronze surfaced. These considerations are quite the same as in bronze-welding, Chapter 18.

*Welding Rod.* The choice between Oxweld No. 25M and Oxweld No. 31T Bronze welding rods depends upon the service conditions to be met. Oxweld No. 31T has greater hardness (105 Brinell as to 96 for Oxweld No. 25M) especially at elevated temperatures (about 74 Brinell at 500 deg. F. for No. 31T as to 58 for No. 25M). On the other hand, Oxweld No. 25M possesses much higher ductility at all temperatures at which it can be used. At ordinary temperatures the ductility of Oxweld No. 31T bronze rod is about 5 per cent, while welds can readily and consistently be secured with Oxweld No. 25M bronze rod having ductility in excess of 30 per cent.

*Welding Technique.* Bronze-surfacing is done with the standard bronze-welding technique described in Chapter 18. Brazo flux should be used and good "tinning" is a vital factor because the layer of weld metal is relatively thin.

Best results are obtained by starting at one point and bronze-surfacing continuously until the job is completed.

The bronze should be flowed on in as thin a layer as possible in order to reduce the amount of subsequent machining. A layer of bronze 1/16 to 1/8 in. thick is usually sufficient.

*Finishing.* When welding is completed, the part should be permitted to cool slowly to normal temperature.

The bronze weld metal can be easily machined so that the part will have the exact dimensions required. The weld metal obtained by the use of the welding rod recommended for bronze-surfacing has unusually excellent machinability because of its soundness.

properties, with maximum wear resistance. When cold, Haynes Stellite alloy is almost as hard as hardened steel and it has the unique property of retaining its original hardness practically unimpaired at the high surface heats developed by friction—and even at a red heat. This property is known as "red-hardness." The importance of "red-hardness" to wear-resistance may easily be appreciated when one considers that all wear is accompanied by heat and that surface temperatures often momentarily approach a red heat even though there may be little evidence of such high temperatures to the eye. All iron-base alloys soften when heated to the red range, but Haynes Stellite alloy, because its base is cobalt rather than iron, retains its hardness practically unimpaired at a red heat. It is this important property of red-hardness which accounts for the superior results obtained with Haynes Stellite alloy.

Two other valuable characteristics of Haynes Stellite alloy are its low coefficient of friction and its ability to take a high polish. These qualities result in less surface heat being developed in contacting parts. This alloy is also highly resistant to chemical corrosion.

## HAYNES STELLITE ALLOY GRADES

Haynes Stellite rod is supplied in three grades—No. 1, No. 12 and No. 6. No. 1 is the hardest and most wear resistant of the three grades. Extreme pressure or heavy shocks are liable to check or chip it, but these difficulties can be overcome by properly backing up and supporting it with steel base metal.

No. 12 is not quite as hard as No. 1 and is slightly less resistant to abrasion. It is, however, much stronger and somewhat more ductile and, therefore, will withstand shock and impact better than No. 1.

No. 6 is not quite as hard as, but is considerably tougher and stronger than, Nos. 1 and 12. While it is tougher, its resistance to abrasive wear is slightly lower. It does not check or chip easily and will withstand heavier shock or impact. Since its coefficient of expansion closely approximates that of carbon steel, No. 6 can be applied to large areas without checks and cracks. It withstands the effect of sudden temperature changes better than the other two grades.

| Grade | Tensile Strength Lb. per sq. in. | Rockwell Hardness of Welded Deposit |
|---|---|---|
| No. 1 | 40,000 | C54 |
| No. 12 | 70,000 | C48 |
| No. 6 | 86,000 | C43 |

*Haynes Stellite Alloy Applications.* The hard-facing process has spread so rapidly in recent years that it is almost impossible to enumerate the many applications in practically every industry. In the metal working industries, all types of dies, punches, shears, cams, etc., have been economically hard-faced with Haynes Stellite alloy. Automotive exhaust valves and seats, clutch release yokes, fuel pump shafts, valve stem ends and rocker arms show 3 to 10 times longer life when protected with this wear-resistant alloy. Where abrasion is intensified by heat as in the iron and steel industry, Haynes Stellite alloy is especially effective for facing hot shearing knives, hot forming and trimming dies, all types of guides, water cooled pokers, coke pusher shoes, etc. Brick and cement industry applications include pug mill knives and push shoes, dies and augers, grinder rings, conveyor screws, crusher teeth and gudgeons. For many years such parts as plowshares and disks, cultivators, subsoil teeth, and grain grinding hammers have been hard-faced in the agricultural field. Progressive mills in the lumber industry have found the hard-facing of hog anvils, chipper bed plates, chipper chutes, etc., to be particularly economical. In excavating and mining fields the hard-facing process finds such applications as bucket lips, dredging cutters, tractor treads, undercutter bits, hand shovels, drag line scrapers, grizzlies, etc. One of the most important hard-facing developments is the application of Haynes Stellite alloy to gate and globe valves for high temperature and high pressure steam service. In fact, almost any conceivable metal wearing part can be economically hard-faced with this alloy for greater life.

*Hard-Facing With Haynes Stellite Alloy.* Haynes Stellite

alloy can be applied with ease to all ordinary steels, to high-carbon and alloy steels including stainless steel, and to cast and malleable iron, the operation resembling bronze-welding.

*Preparation of Piece.* It is important that all rust, scale or other foreign substances be removed from the area to be hard-faced, preferably by grinding, machining or chipping. If these facilities are not available, the surface can be cleaned with a file or wire brush, but this method often leaves scale or other foreign material which must later be floated out during the hard-facing operation. If recesses are cut to receive the Haynes Stellite alloy, all internal corners should be well rounded.

*Preheating.* When preheating is necessary it can be done as for ordinary cast iron welding. If the part is bulky or the surface is large, a temporary firebrick furnace fired with charcoal is preferred. Small pieces can be preheated sufficiently in the blowpipe flame. The material in any instance should be brought up to a dull red heat, approximately 1,200 deg. F. and maintained at this temperature during the entire welding process.

*Blowpipe Adjustment.* The flame for hard-facing with Haynes Stellite alloy must contain an excess of acetylene, and should be adjusted so that the flare or outer cone denoting an excess of acetylene extends double the length of the inner cone. This is important and must be done to insure a satisfactory sweating of the base metal. Unless this type of flame is used the deposited metal tends to pile up instead of spreading freely. Foaming and bubbling of the molten metal will indicate an insufficient amount of acetylene; on the other hand a heavy black carbon deposit will indicate too much. The blowpipe should be held close enough to the work so that the inner cone of the flame is not more than 1/8 in. from the surface.

*Hard-Facing Steel.* The procedure for hard-facing steel with the blowpipe consists in bringing a small section of the surface to a sweating temperature. This is done by playing the blowpipe on one corner section of the surface until the carbon deposit from the excess acetylene flame disappears and the metal begins to sweat. The end of the Haynes Stellite rod is then brought into the flame and allowed to melt and spread over this sweating area. If the conditions are correct the

Haynes Stellite alloy will immediately spread and flow like solder on a properly heated and tinned surface.

It is usually possible and preferable to build-up the entire coating to the desired thickness in one operation.

During the hard-facing operation any particles of rust or scale encountered on the steel should be floated to the surface. If they are allowed to remain and are covered by the deposit, they will in nearly every case produce blowholes. Other causes of pin holes are too small an excess of acetylene in the flame, application of the welding rod before the base metal has reached a sweating surface heat, and too sudden removal of the welding flame from the pool of molten metal. To remove these blowholes, the metal around the hole should be heated to a red heat, melting down into the hole so as to float off the impurity causing it. The molten metal should be allowed to close in slowly by adding welding rod and the heat should then be drawn away slowly from the hot spot into the body of the base metal to prevent quick cooling. As a general rule no flux is used when Haynes Stellite alloy is applied to steel. Penetration and puddling should be avoided as this dilutes the alloy with iron and lowers its resistance to abrasive wear.

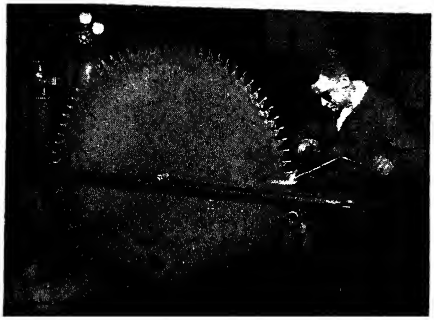


Fig. 132. Hard-facing the teeth of a rotary saw with Haynes Stellite.

When Haynes Stellite alloy is properly applied to steel with the oxy-acetylene blowpipe a straight line bond will result. Though there is practically no penetration between the alloy and steel, the bond is actually stronger than the deposited metal. The deposited metal is pure Haynes Stellite alloy undiluted with iron from the base metal, and hence possesses maximum wear resistance.

*Cooling.* At the completion of the hard-facing operation the same cooling procedure should be used as in cast iron welding, bearing in mind that Haynes Stellite alloy has relatively low

ductility. As a rule the part should be cooled slowly by covering with asbestos fiber cement, slaked lime, wood ashes, or some other material of similar heat insulating characteristics. Small parts can be wrapped in asbestos paper.

Haynes Stellite rod applied as recommended will form a very strong bond with the base metal and will not break loose at the bond. If surface cracks are present, they can generally be repaired by the same method as blowholes. On many jobs surface cracks are not detrimental, since they usually run only through the deposited metal and stop at the base metal.

*Hard-Facing Cast Iron.* If the base metal is cast iron, it will not sweat like steel and a little less acetylene should be used in the flame than for steel. Haynes Stellite alloy does not flow as readily on cast iron as on steel, and it is usually necessary to break the surface crust with the end of the rod. A cast iron welding flux is usually necessary and it is usually best to weld on a thin coating of Haynes Stellite alloy first and then go over it again and build-up to the desired thickness. Haynes Stellite alloy and cast iron have about the same melting point, hence care must be taken not to melt the base metal too deeply. If the cast iron is very thin it will be helpful to back it up with wet asbestos or carbon paste to avoid melting it.

Fig. 133. Haynes Stelliting a steam valve disk.

*Hard-Facing Other Materials.* All kinds of steel can be hard-faced with Haynes Stellite alloy by the oxy-acetylene process with the exception of high manganese (Hadfield) steel. Monel metal is easy to hard-face; copper is relatively difficult; brass and other alloys of low melting point cannot be.

Nitralloy can be hard-faced more easily if a good bronze-welding flux is spread on the surface before the part is brought to a red heat. This prevents the formation of an oxide which is hard to float off. The nitrided "case" should be ground away from the portion to be hard-faced.

High speed steel should be fully annealed before Haynes Stellite alloy is applied. Heat should be kept as even as possible during the welding operation and afterward the whole piece should be brought up to an even red heat and allowed to cool very slowly. However, the hard-facing of high speed steel is as a general rule unsatisfactory because, in a great number of cases, cracks will be found in the steel below the coating.

Stainless steel, since it has a higher rate of expansion than plain carbon steel, should be very evenly heated and slowly cooled to prevent uneven internal stresses. Large pieces should be heated in a furnace to a dull red heat and cooled in the furnace.

*Hard-Facing Costs.* In the vast majority of cases, hard-facing deposits of Haynes Stellite alloy range from 1/16-in. to 1/4-in. in thickness. Parts requiring a thickness greater than 1/4-in. are usually rebuilt with Hascrome alloy or steel to within 1/16-in. to 1/4-in. of finished size before hard-facing. The amount of Haynes Stellite rod required for hard-facing any particular part can be quickly estimated by a simple formula.

$$\frac{T \times W \times L}{3} = \text{pounds of Haynes Stellite alloy required}$$

T = thickness of deposit in inches
W = width of deposit in inches
L = length of deposit in inches

The cost of oxygen, acetylene and labor is not so easily determined because of the large number of combinations of shapes and sizes of wearing parts. An average taken from several hundred jobs showed that it required 41 min. to apply 1 lb. of Haynes Stellite rod, with gas consumption of 26 cu. ft. of oxygen and 30 cu. ft. of acetylene.

*Hard-Facing With Hascrome Alloy.* When applying Hascrome rod to steel, a flame containing an excess of acetylene halfway between a neutral and a carburizing flame should be

used. A neutral flame causes boiling and produces an unsatisfactory result. Hascrome rod should be applied when the steel surface is just at a sweating heat—puddling being unnecessary.

When applying Hascrome alloy to cast iron, a small area at a time should be heated with the blowpipe, breaking the surface crust with the end of the rod. A little puddling is usually necessary and a good flux is often helpful. Because of the low melting point of cast iron, considerable care must be taken when working up thin surfaces or edges and corners.

The hardness of the deposited Hascrome alloy depends on the amount of acetylene used in the flame and upon the rate of cooling. A small excess of acetylene is necessary to prevent the rod from boiling. A much greater excess can be used if an exceptionally hard deposit is desired. In general it may be said that the greater excess of acetylene and the slower the rate of cooling the harder the deposit will be. A quenched deposit is not as hard but is tougher than slowly cooled metal.

*Hard-Facing With Composite Rod and Tube Rod.* Haystellite composite rod and Haystellite tube rod should be applied with a flame containing a small amount of excess acetylene and the application made without penetrating as deeply into the base metal as in ordinary steel welding. A certain amount of stirring with the rod is necessary to obtain the most even distribution of the deposited metal. Composite Rod and Tube Rod do not flow as freely as ordinary welding rods due to the presence of the Haystellite tungsten carbide particles which are not melted during the application. As in the case of applying Hascrome alloy, it is best to avoid keeping the deposit molten for too long a period. If it is necessary to heat-treat the base metal to provide greater hardness and toughness, this can be done without detrimental effect to the hard-facing layer by quenching in oil—not water.

*Hard-Setting With Haystellite Inserts.* As Haystellite tungsten carbide inserts cannot be applied to wearing surfaces in the same manner as hard-facing rod, they are applied by tacking individual pieces in place on the wearing surface and then tying them in by covering them with High Test steel. This operation is called hard-setting.

The size and spacing of Haystellite inserts will vary with

individual hard-setting applications, depending on the nature of the wear and the type of equipment to be faced. The procedure for hard-setting with Haystellite is briefly as follows: The surface to be faced is first ground free from rust and scale. One Haystellite insert at a time is picked up by tacking High Test steel rod to it. A small area of the steel base metal is then melted with the blowpipe, using a slight excess of acetylene in the flame, and approximately one-third of the body of the Haystellite insert is submerged into the molten puddle. A thin coating of rod is then flowed around the insert.

Fig. 134. Oil well bit protected against abrasive wear by means of Haystellite inserts and a final coating of Composite Rod.

For most accurate spacing it is recommended that the inserts be set in grooves which have been prepared by milling, forging or grinding. On most parts, a $\frac{1}{16}$-in. to $\frac{1}{8}$-in. layer of composite rod is usually applied over the Haystellite inserts as a final coating.

## SUPPLEMENTARY READING

Detailed information on the properties, uses, and procedures for applying Haynes Stellite alloy, Hascrome alloy and Haystellite tungsten carbide may be had from the many publications issued by the Haynes Stellite Company, Kokomo, Indiana.

## CHAPTER 32

# Heating

SCOPE *of Applications.* Quite apart from its use in welding and cutting, the oxy-acetylene flame provides a most convenient source of intense localized heat for a wide variety of other applications. These may be grouped under several headings: preheating; forming and bending; melting; metallurgical; wood treating.

*Advantages.* Although oxygen and acetylene would seem, on first thought, to constitute a more expensive fuel than coke, coal, city gas or gasoline, the intensity of the oxy-acetylene flame and the ease with which it may be concentrated directly upon the parts to be worked make it possible to do the work with so much less fuel that the fuel cost with the oxy-acetylene process is, in most cases, actually less than when other fuels are used. In addition, there is a marked saving of time and labor.

The oxy-acetylene blowpipe saves time by making it unnecessary to dismantle a large structure or machine in order to heat the particular part to be bent or straightened. With this process, the source of heat is carried to the work rather than the work to the source of heat, as is necessary with ordinary methods.

In many production operations where the design of the product is not readily adaptable to stamping or forging, or where the cost of special equipment for such work is prohibitive, the oxy-acetylene blowpipe offers a simple, inexpensive method of bending sheet or plate to form.

### PREHEATING

A number of references have already been made to the use of the welding blowpipe flame as a convenient means of preheating small parts for welding. The heat can be applied exactly as required, and if there are sections of varying thick-

ness it can easily be concentrated more on the thicker member. On small intricate castings such control is frequently a most useful factor.

## FORMING AND BENDING

Heating applications involving forming and bending range all the way from the most delicate detail of ornamental iron work to the straightening of the sternpost on a giant ocean liner.

*Sheet Metal.* The removal of dents is a most important heating application for such sheet metal products as automobile bodies and fenders, street car and bus bodies, buckets, ladles, kettles, tanks, pots and stills.

*Ornamental Iron.* In the hands of a skilled craftsman, the oxy-acetylene blowpipe can, through its unique ability to combine severing, welding and heating, produce ornamental iron work of unsurpassed beauty. In much of this work, the fact that just the right spot can be heated quickly to just the right temperature is most important.

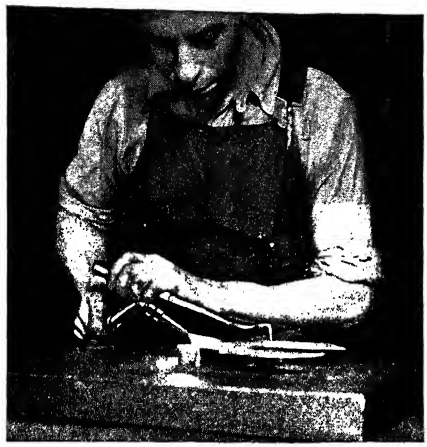


Fig. 135. Local heating of shoe dies permits accurate bending to shape.

*Structural Shapes.* Structural shapes such as angle iron, channels, tees and other sections are frequently formed and shaped through the aid of local heating by the blowpipe flame.

Thus, in making a square or rectangular angle iron frame for a guard or the top of a support, a most convenient method is to use a single piece of angle iron of the proper length to form the frame.

Mark the points which will form three of the corners. On one leg of the angle mark 90 deg. vee notches at these points and cut out the triangular pieces with a cutting blowpipe. Cut each end of this leg at 45 deg. Clamp the uncut leg of the

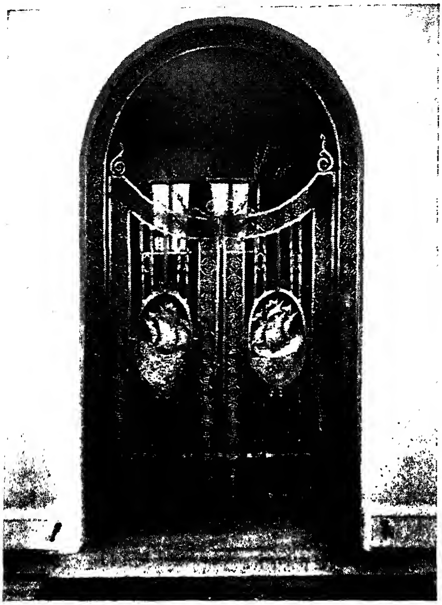


Fig. 136. In ornamental iron work, local heating with the blowpipe facilitates the shaping of intricate details.

angle to the top of the welding table between the first and second marks on the angle. Heat the uncut leg at the first mark, moving the flame back and forth across the leg until it is evenly heated to a good red. Then take the free end of the angle and bend it up at right angles to the clamped portion. Check with a try-square. Repeat the bending at the two other corners. When all the bends are made the cut edges of the notches and the ends of the uncut leg will be in position for welding to complete the frame.

Channels used for monorail overhead cranes can also be curved exactly as desired after heating with the blowpipe.

The straightening of bent automobile chassis members is another important application under this heading.

*Heavy Plate.* The exact shaping of heavy plate in ship building is greatly facilitated by heating with large capacity oxy-acetylene blowpipes, as is the straightening of ship plates that have been damaged through collision or otherwise.

Flanging of heavy plate in ship yards and boiler shops is a similar time-saving method. For example, to form a $4\frac{1}{2}$-in. flange at 30 deg. on a conical tube sheet 13 ft. 9 in. in diameter and $\frac{7}{8}$-in. thick formerly required 80 hr. when the operation was

Fig. 137. Use of the blowpipe for heating effects economies in flanging tube sheets.

done by heating the whole sheet in a furnace. Using local oxy-acetylene heating, the job is now done in 9¼ hr. and the fuel cost is only half as much as it was before. See Fig. 137.

## MELTING

There are certain metal melting operations which are essentially heating applications, as no joining of metals is involved. These include filling dents with solder, and rebabbitting bearings.

*Filling Dents.* Slight depressions or dents in automobile bodies and fenders are frequently treated by simply filling up the dent with solder, smoothing carefully and repainting. Small oxy-acetylene blowpipes are ideal for this work.

*Rebabbitting Bearings.* Old bearings can be quickly melted out with the blowpipe flame. Sometimes in the case of heavy machinery the operations of rebabbitting can be done right in place, saving the time and expense of dismantling. The flame can also be used to melt babbitt metal in the ladle.

*Special Furnaces.* An interesting heating application is the construction of a special furnace for determining the softening points of the pyrometric cones used in the ceramic industry to check time-temperature conditions within the kilns. Two oxy-acetylene blowpipes furnish sufficient heat to bring the furnace temperature up to 3,335 deg. F. with great ease.

## METALLURGICAL

The localized, easily controlled heat possible with the oxy-acetylene flame is utilized to advantage in certain metallurgical operations such as annealing.

## WOOD TREATING

An antique finish of decorative interest for house or building trim can be given wood by treatment with the oxy-acetylene flame.

The wood to be treated is first given a coat of linseed oil and allowed to stand for a few days. The blowpipe flame is then played over the surface until the wood has been charred to a depth of about ⅛ in. This must be done evenly, going over a large area at a time to avoid burning holes in the wood. The burning procedure affects principally the softer part of the

wood, leaving the hard grain structure relatively untouched, so that when the charred layer is brushed off with a stiff wire brush, the grain stands out in relief, and the general appearance of the wood is darkened and old. Successive coats of filler, oil and wax complete the illusion of a soft-toned, antique wood. Heavy beams are sometimes rough-hewn before applying the oxy-acetylene flame to heighten the final effect. The process has been used successfully in the reproduction of fine antique furniture.

In Australia, where the wood used for poles is so dense that it resists pressure treatment with preservatives, the oxy-acetylene flame is being used to char the surface and thus form a porous surface that will better absorb and retain the preservative.

## CHAPTER 33

# Silver Soldering

CHARACTERISTICS. Silver soldering by the oxy-acetylene process is an operation quite similar to bronze-welding that has gained considerable industrial importance within recent years. Long used by jewelers for joining silver, silver solder has now come into industrial use for joining other metals as well through the perfection of suitable formulas by the manufacturers of this type of solder. Silver solders now available have melting points as low as 1,200 and 1,300 deg. F.

The two principal reasons for silver soldering instead of bronze-welding in certain cases are that silver solder has a lower melting point than bronze and a range of lighter colors can be obtained with a silver soldered joint.

*Resistance to Vibration.* Silver solder will stand up under conditions of constant vibration, a fact which is demonstrated by its use on delicate vibrating parts of radio loud speakers and in many other ways where excessive vibration is a factor. Joints silver soldered by the oxy-acetylene process have a tensile strength ranging from 40,000 to 60,000 lb. per sq. in. Silver solder flows so evenly under the oxy-acetylene flame that it penetrates quickly and deeply into all parts of the joint, leaving no pin holes.

*Corrosion Resistance.* Another important property of silver solder is its high resistance to corrosion. Chemical agitator kettles and other items of chemical equipment are frequently fabricated of oxwelded Monel metal or nickel with flange type welds. This gives a strong joint with a stiffening rib on the outside, but the inside of the container is apt to have a slight crevice or unevenness. The chemicals within the container will first attack the unevenness caused by the weld. This may be remedied by silver soldering the inside of the seam, thereby insulating it against chemical action. This type of combina-

tion seam is used not only for chemical equipment but also in dairy, textile, dyeing and laundry equipment. By means of this combination seam, the advantages of the strength of ox-welded construction are secured and also the corrosion resisting qualities of the silver alloy are obtained.

*High Electrical Conductivity.* Because of its high electrical conductivity and resistance to shock and vibration, silver solder has been found to be most satisfactory on electrical connections.

*Procedure for Silver Soldering.* The procedure for applying silver solder by the oxy-acetylene process is very simple and easy for anyone familiar with the welding flame to learn.

*Preparation of Joint.* As in good welding technique, the parts to be soldered should first be cleaned thoroughly either mechanically or chemically. The edges of the joint should be smooth and should fit tightly, as only a film of silver solder is usually needed to give a sound joint. It is wasteful to use it as a filler. Good fluxing is as important as it is in bronze-welding. For general soldering, a saturated solution of borax may be used, which is most effectively applied with a brush, painting the parts to be joined and the soldering wire itself.

Fig. 138. Silver soldering an automobile ignition conduit.

*Soldering Technique.* The oxy-acetylene flame produced by a small sheet metal welding blowpipe or a lead burning blowpipe will be most suitable for this work. The joint and surrounding metal should be gently preheated after fluxing, taking care that the base metal does not reach the melting point. When sufficient preheat has been applied, the flame should be moved away and the silver solder brought to the joint where it will melt and flow quickly if the parts have been properly fluxed and preheated. The knack of heating to

the proper temperature is quickly developed with a little practice. The silver solder should be melted simply by the heat of the base metal; the flame should never touch the solder or a porous joint might result.

Fig. 139. Copper vessels fabricated by silver soldering with the oxy-acetylene flame.

CHAPTER 34

# Air-Acetylene Flame

THE air-acetylene torch is a useful companion to the oxy-acetylene blowpipe. It operates effectively in a lower temperature range, as the temperature of the flame produced by burning a properly proportioned mixture of acetylene and air is considerably lower than that of the oxy-acetylene flame. There are, however, literally hundreds of applications in metal working and in various other trades where a lower flame temperature is sufficient.

## AIR-ACETYLENE OUTFIT

A typical air-acetylene outfit consists of:

1. A small tank of Prest-O-Lite dissolved acetylene, the same type that is known everywhere through its use for truck and motorcycle lighting.
2. A pressure regulator which automatically holds the gas at a uniform and correct working pressure, insures minimum gas consumption and provides a means for reducing the gas pressure.
3. A length of hose that is specifically manufactured for handling acetylene gas under pressure.
4. A torch handle to which can be attached stems for various work.
5. Four stems for fine, light, medium and heavy open flame soldering, heating and brazing.
6. A soldering copper for enclosed flame work. This consists of a soldering iron heated and kept at a constant temperature by means of an air-acetylene flame enclosed within the head.

With these stems a tremendous variety of work can easily be carried out.

## ADVANTAGES OF THE PROCESS

There are many advantages which are inherent in the air-acetylene flame over liquid or other gas fuel flames. It pro-

duces a higher flame temperature than gasoline, coal gas or natural gas. It produces a flame that is non-oxidizing and non-carbonizing and it can be perfectly and instantly controlled.

By means of the blowpipe type stems the outfit is conveniently used in any position, in a corner or places hard to reach with other types of equipment. The small but intense flame can be focused exactly where it is needed. Because each stem contains an individual mixer correct proportions of acetylene and air are automatically maintained, always insuring the proper flame.

Another outstanding advantage of this type of outfit is that it is completely portable and can be brought into action immediately. No preheating of the stem is necessary, simply turn on the gas, light the torch, and start to work. Obviously the flame can be turned out between jobs. Of particular worth is the simplicity of the outfit. Work can be started with the mere lighting of a match or a friction lighter.

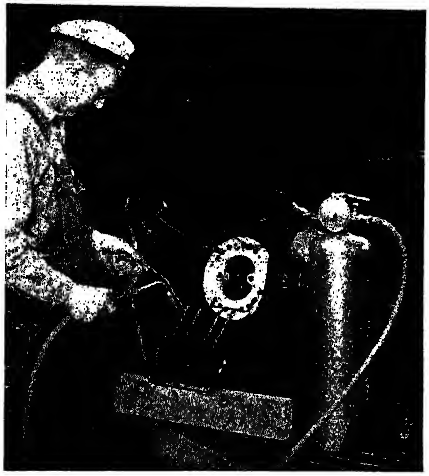


Fig. 140. Soldered connections on electrical equipment are easily made with an air-acetylene torch.

### TYPICAL APPLICATIONS

Air-acetylene torches are replacing old fashioned equipment in every line of work. Automobile and radio repair shops find them most convenient for general electrical work; tinsmiths, sheet metal workers and roofers choose them for standard equipment; battery shops use them for sealing batteries; farmers find them indispensable for many odd jobs around the farm; creameries, dairies and cheese factories use them for soldering milk cans and cheese vats; they are standard equipment for laboratories of all types; dentists use them for drying out molds, melting

gold, castings, infusions, inlays and the most delicate dental soldering; painters, decorators, ship yards, dry docks and contractors find the paint burning outfit ideal for removing old varnish and paint from wood, canvas and bricks. In every industry the air-acetylene torch should be standard equipment for soldering, heating and brazing operations. The flame operations are clean and without grime or odor. Little time is required for preparation and the proper amount of heat can be applied exactly where needed, making the apparatus efficient, convenient and economical to operate.

## ATTACHING SOLDER-TYPE FITTINGS TO COPPER TUBING

The general technique of using the air-acetylene torch may be illustrated in connection with a recent application that is rapidly increasing in importance. This is the use of the new sweat-type or solder fittings for copper and brass tubing (see Chapter 24). The air-acetylene torch is ideal for attaching these fittings as it gives a hotter, more concentrated flame and the job is completed in less time than would be required by other means.

Fig. 141. The air-acetylene flame is ideal for solder-type copper fittings.

Briefly this work should be carried out as follows. The end of the tube to which a fitting is to be applied, and the inside of the fitting itself should be polished and cleaned thoroughly with fine steel wool until the parts to be sweated together are clean and bright and free from oxide. Files are not recommended for this work because they scratch the surface and may cause a poor joint. Do not forget to polish the inside of the fittings because the surfaces to be soldered must be absolutely clean. A non-corrosive soldering flux should then

be applied to the clean surfaces. Do not use too much because it may form bubbles when it is heated and this will prevent the solder material from being drawn into the joint and around all of the surfaces to be joined. Outside the fitting any flux should be wiped off, otherwise the solder has a tendency to run over the surface of the tube wherever there is flux. This would spoil the finished appearance.

Light the torch, and adjust the flame to the right size. Then play the flame with a brushing motion over the portions to be soldered until they have become heated to the soldering temperature. Keep the flame moving so that overheating is prevented. The temperature for soldering can be tested by touching the solder to the point where the solder is to be introduced (this depends, of course, on the design and make of the fitting), keeping the flame away from the solder while making the test. It is important that the joint not be overheated.

Fig. 142. Installing copper tubing with solder-type fittings.

When the joint is the correct temperature, remove the flame completely and apply the solder which will automatically, by capillary attraction, be sucked into the joint. When a line of solder shows around the end of fitting, presumably sufficient solder has entered the joint. The joint can be reheated for an instant and, if necessary, the solder reapplied until the joint is completely filled. It will then be completed. All surplus solder from around the edges of the joint should be removed by a light camel hair brush. This will show whether the joint is completely filled. Use a wet cloth to cool the joint rapidly.

## SUPPLEMENTARY READING

For a more detailed discussion of the air-acetylene flame and its uses see "101 Uses for the Air-Acetylene Flame", published by The Linde Air Products Company.

## CHAPTER 35

# Principles of Oxy-Acetylene Cutting

OXY-ACETYLENE cutting is a process of severing ferrous metals by utilizing the rapid chemical reaction which takes place between heated iron and oxygen. The ease with which heated iron oxidizes in air has been referred to on page 109. With oxygen, the action becomes intensely rapid and so much heat is liberated that the oxide formed is melted and heated to incandescence. The fact that iron oxide melts at a lower temperature than many steels and that iron oxide is soluble in molten iron has been mentioned on page 110.

The oxide formed in oxy-acetylene cutting is black iron oxide, which has the chemical formula $Fe_3O_4$. Chemically, the complete reaction is expressed as follows:

$$\begin{array}{ccccc} 3Fe & + & 2O_2 & = & Fe_3O_4 \\ \text{iron} & \text{plus} & \text{oxygen} & = & \text{iron oxide} \end{array}$$

The heat liberated by this reaction is sufficient not only to melt the iron oxide but also to melt some of the steel or iron. As a result, slag produced in cutting plain carbon steel consists of a mixture of 60 to 70 per cent black iron oxide and 30 to 40 per cent metallic iron.

Theoretically, 4.58 cu. ft. of oxygen is required to oxidize 1 lb. of iron to black iron oxide. In actual practice, the consumption of cutting oxygen has been found to vary from 3½ to 5 cu. ft. per lb. of iron removed.

*Cutting Blowpipes.* In the practical application of the oxy-acetylene cutting process, the jet or stream of oxygen which does the cutting issues from an orifice in the center of the nozzle or tip of the cutting blowpipe. The flow of cutting oxygen is controlled by a conveniently located valve on the blowpipe handle. The cutting oxygen jet can be guided along any line desired, whether straight, curved or irregular, and can also be inclined at an angle, as in cutting bevels.

Surrounding the cutting orifice in the nozzle or tip are several smaller orifices for oxy-acetylene heating flames, Fig. 143. These are used to preheat the metal to the kindling temperature, which is 1,400 to 1,600 deg. F. in the case of plain carbon steels. Theoretically, the heat of the cutting reaction should be sufficient to keep the cut going after it has started. In practice, however, the heating flames are kept burning constantly to insure continuous, rapid cutting.

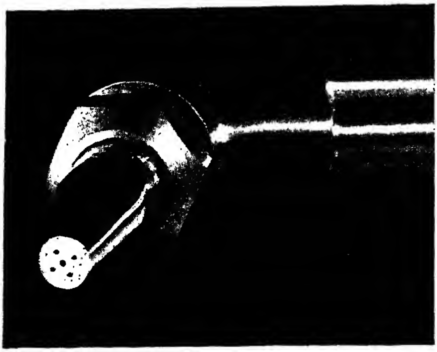


Fig. 143. Orifices in nozzle of cutting blowpipe.

*Cutability*. The application of oxy-acetylene cutting, or flame cutting as it is also called, is limited to iron, steel and the ferrous metals in general.

As cutting is an oxidation reaction, this may seem somewhat strange, for there are other metals which react with oxygen more readily than iron does, and yet they can not be cut. The answer seems to lie in the physical properties of the oxide formed. Aluminum, for example, oxidizes more rapidly than iron but the aluminum oxide formed has such an extremely high melting point that it is practically infusible. Consequently, its formation interferes with any cutting action.

In the case of iron and steel, the oxide melts readily and flows away, exposing a fresh surface of metal to the action of the cutting jet.

All ferrous metals are not, however, cut with equal facility. Those most readily cut are the plain carbon steels with from 0.10 to 1.70 per cent carbon. Within this range, the cutability improves somewhat as the carbon content increases. Cast iron and certain alloy steels, particularly the stainless steels, are more difficult to cut and special cutting techniques are required (see Chapter 37).

*Manual and Machine Cutting*. Cutting blowpipes are guided

either by hand or by machine. Manual flame cutting is used with entirely satisfactory results for a wide range of cutting operations. Machine flame cutting is finding constantly increasing application, due to the greater speed, accuracy and economy possible with machine-guided blowpipes. Machine cutting is used mainly for metals that can be cut by the technique used for plain carbon steels.

*Effect of Cutting on Steel.* Flame cut edges or surfaces in normal commercial practice are actually superior in many respects to the body of the metal due to the heat-treatment given the surface layer to a depth of about 1/16 in. by the heat of the cutting reaction. Machine flame cuts have physical properties practically equal to those of milled or machined surfaces and even manual flame cuts, which are naturally somewhat less smooth than machine flame cuts, are definitely superior to sheared and friction sawed edges. No mechanical violence is done to edges that are flame cut; instead, the surface is left in a superior metallurgical condition.

Fig. 144. By means of oxy-acetylene cutting, steel plate can be quickly shaped as needed on location.

These conclusions are substantiated by engineering data.*

* See particularly the following:

"Flame-Cutting Steel Plate", J. H. Zimmerman, *Mechanical Engineering,* June, 1936.

"A Comparative Study of Cutting Methods as Applied to Structural Steel", J. H. Zimmerman, *Mechanical Engineering,* July, 1935.

"Tests on Flame-Cut Wind Connections", O. E. Hovey, *Engineering News-Record,* April 30, 1931.

"Flame Cutting of Low Carbon Steel", J. R. Dawson, *Journal of the American Welding Society,* June, 1932.

"Flame Cutting of Structural Steel", S. W. Miller and J. R. Dawson, *Engineering News-Record,* November 1, 1928.

"Tests on Structural Details Flame-Cut from I-Beams", *Engineering News-Record,* November 1, 1928.

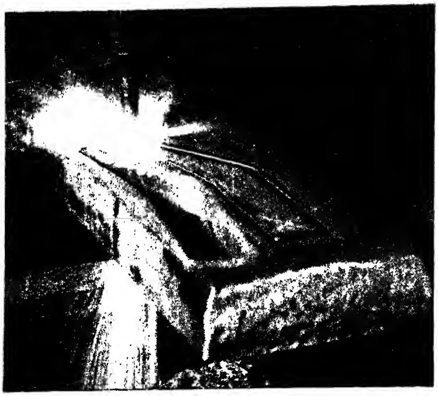


Fig. 145. Cutting dipper teeth from preheated chrome-vanadium steel.

*Preheating High-Carbon Steels.* Steels with carbon content higher than 0.35 per cent and most alloy steels should be preheated to about 500 to 600 deg. F. before cutting. This will avoid the surface checking which results when such steels are cut at normal temperatures.

Steels of these types may also require annealing or heat-treatment after cutting. Definite recommendations as to the proper procedure can be obtained from the manufacturers of cutting blowpipes.

CHAPTER 36

# Manual Flame Cutting

THE cutting technique most commonly used is that employed for severing plain carbon steels and low alloy steels. Manual flame cutting with this technique is discussed in this chapter; the cutting of heavy sections in Chapter 38; machine cutting in Chapter 39. The special techniques that are required in cutting cast iron and other materials of lower cutability are described in Chapter 37.

*Preparation for Cutting.* Since cutting action is dependent upon the chemical reaction beween the *metal* and the oxygen, it is desirable that the surface should be cleaned before attempting to cut. Dirt and scale should be scraped off or removed with a stiff wire brush. Layers of paint and other foreign matter slow down the action and waste oxygen.

Where cutting has to be done on material coated with a lead-base paint, the operator should wear a mask of a type that will supply him with fresh air. See Recommendation J-17, Chapter 40. In addition, Recommendations J-14 to J-16 and J-18 to J-21 should be studied carefully.

## CUTTING PROCEDURE FOR STEEL

*Straight Line Cutting.* For practice in cutting, it is best to start with a piece of ½ in. steel plate about 6 in. wide. Rule a chalk line about ½ in. from one edge of the plate and place the plate so this line just clears the far side of the welding table.

Insert the proper size cutting nozzle or tip in the cutting blowpipe and adjust pressures for ½ in. metal, in accordance with the blowpipe manufacturer's chart. Then put on goggles, light the blowpipe, adjust the preheating flames to neutral, and switch off the cutting oxygen.

The blowpipe is now ready for use. With the right hand, grip the blowpipe handle so as to permit instant control of the cutting oxygen valve lever, which is usually operated by either the thumb or forefinger. With the left hand, steadied when-

ever possible by resting the elbow or forearm on a convenient support, hold the forward part of the blowpipe so as to guide the nozzle along the line of cut.

To start cutting, hold the blowpipe with the nozzle perpendicular to the surface of the plate and with the inner cones of the heating flames about 1/16 in. above the end of the chalk line on the edge of the steel plate. Hold the blowpipe steady until this spot has been raised to a bright red heat, then slowly press down the cutting valve lever and move the blowpipe slowly, but steadily, along the chalk line. If the cut has started properly, a shower of sparks will fall from the under side of the plate. This indicates that the cut is penetrating clear through. The movement of the blowpipe should be just fast enough so the cut continues to penetrate the plate completely.

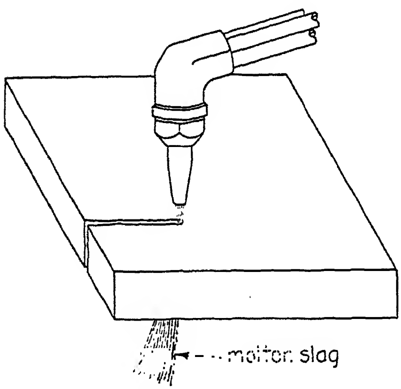


Fig. 146. Position for cutting steel.

If the blowpipe is moved too rapidly, the cutting jet will fail to go clear through the plate and cutting will stop. Should this happen, immediately close the cutting valve and preheat the point where the cut stopped until it is a bright red. On opening the cutting valve there should be no difficulty in restarting a cut.

If, on the other hand, the blowpipe is not moved rapidly enough, the heat of the heating flames will tend to melt the edges of the cut, producing a very ragged appearance, or at times fusing the metal together again. With a little practice, however, the student will soon be able to make a clean, sharp, narrow cut.

At first the beginner may be surprised to find that although he has apparently cut through the plate, still the two pieces hold together. What has happened is simply that some of the slag produced by the cutting action has bridged across and on cooling holds the two pieces of plate together. This slag is

quite brittle, so the plates can be easily separated with a blow from a hammer.

*Guided Cutting.* Resting the cutting nozzle against a straight edge or other guide, as shown in Fig. 147, is helpful in making smooth hand cuts.

*Curves and Designs.* When the student has become proficient in making the straight cut described, he should vary the experiment by marking simple designs or curves on a piece of 3/8 or 1/2 in. plate and then practicing until he is able to follow the lines smoothly with the blowpipe.

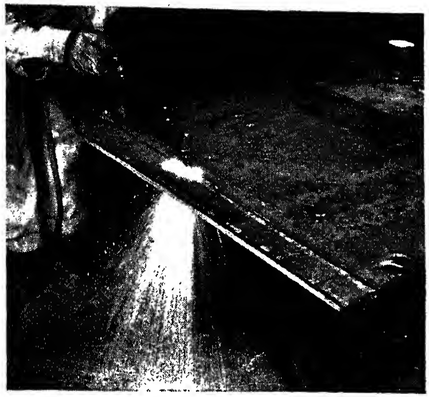


Fig. 147. For greater accuracy in hand cutting, the cut may be guided by means of a bar or a piece of angle iron clamped to the plate.

## BEVELING

Beveling is a common operation with the cutting blowpipe and one that should be mastered by all operators. This is done by holding the blowpipe head at an inclined angle instead of vertically.

For example, place a piece of 1/2 in. or thicker plate so one edge projects 3 or 4 in. over the side of the welding table. Incline the blowpipe head at an angle of 45 deg. to the top surface, and cut a triangular prism off the edge. After the cut is finished, the piece of plate remaining will have one edge beveled at an angle of 45 deg.

Blowpipe control during beveling is somewhat more difficult than when making a vertical cut, so considerable practice will be required. The student should not proceed to another experiment, however, until he is able to produce a satisfactory bevel.

Where the angle of bevel allows, one edge of the cutting nozzle may rest on the work as a support. The nozzle can also be guided by means of a length of angle iron.

## PIERCING A SMALL HOLE

Support a small piece of ½ in. steel plate on two firebrick on top of the welding table. Hold the blowpipe just over the center of the plate until the heating flames have heated a round spot bright red.

Open the cutting valve very gradually and at the same time raise the nozzle away from the work slightly to avoid blowing slag back into the blowpipe nozzle. It will be found that a small round hole can quickly be pierced right through the plate. The cutting blowpipe thus provides a quick and efficient method for making holes in steel plate.

## CUTTING LARGER HOLES

Where a hole of larger size is desired in the plate, the proper procedure is as follows: First mark with chalk the line that will form the edge of the hole (which of course may be circular, rectangular or irregular). Then at some point inside of this outlined area pierce a hole with the cutting blowpipe as described above. Start a cut from this point, working toward and then following the line that has been drawn on the plate. In this way the hole will have clean, sharp edges all around.

Truly round holes may be made with the help of a radius bar or a compass, one leg of which is fixed at the center and the other is made by the blowpipe nozzle.

## CUTTING RIVETS

The fastest and most economical method of removing rivets is to use a special low velocity rivet cutting nozzle. The stream of low velocity oxygen quickly oxidizes the rivet head without affecting the adjacent plate, as the low velocity stream will not penetrate the layer of scale on the plate without considerable preheat. The rivet head is removed long before the scale becomes heated. This method is 50 per cent faster than the standard nozzle in cutting buttonhead rivets and is the only satisfactory way of cutting countersunk rivets.

*Rivet Cutting with Low-Velocity Nozzle.* The Oxweld low-velocity rivet cutting nozzle has a large diameter cutting oxygen orifice with three heating flame orifices above it.

The nozzle should always be placed in the blowpipe so that the heating orifices are above the cutting oxygen orifice when the blowpipe is held in the rivet cutting position. The most economical oxygen pressure is 45 to 55 lb. per sq. in.

When countersunk rivets are being removed from vertical sheets, the blowpipe is held horizontally and turned so that the cutting nozzle also points horizontally. The nozzle is tilted upwards about 15 deg. and the heating flame held on a point slightly below the center of the rivet head, Fig. 148. When the heated area becomes dull red, move the blowpipe up a slight distance, still maintaining the slight upward tilt, and open the oxygen cutting valve. The upward shift and opening of the cutting valve are practically simultaneous, which directs the

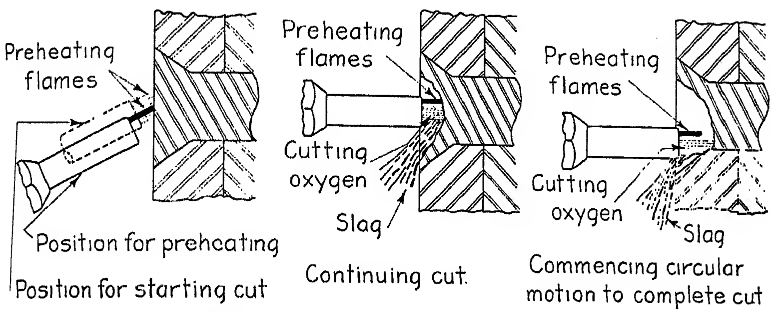



Fig. 148. Positions of low velocity nozzle in cutting countersunk rivets.

cutting oxygen on the heated area. Since the position of the heating flames is eccentric, the blowpipe should always be moved so the cutting stream will follow the preheat.

Hold the blowpipe steady, with the cutting stream directed along the center line of the rivet. As the metal is burned the angle of tilt should be decreased, finishing with the nozzle perpendicular to the sheet, and the cutting stream directed along the center line of the rivet.

When the coned head has been burned through and the body or shank of the rivet reached, the remainder of the head should be removed in one circular wiping motion. The blowpipe should be held with the nozzle pointing at the base of the countersink and moved once around this circumference.

The procedure for removing buttonhead rivets is similar to that for countersunk rivets.

Start at a point slightly below the center of the head with the nozzle pointed slightly upwards, Fig. 149. When this area has been preheated, move the blowpipe up so that the cutting stream will be directed on this area, holding the blowpipe steady with the nozzle pointed along the center line of the rivet. When the head has been burned and the shank or body of the

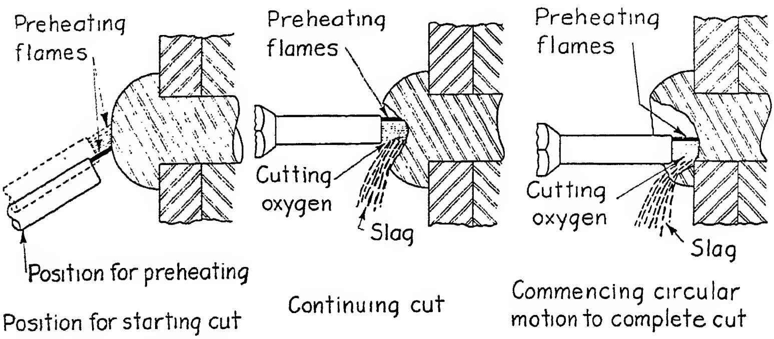



**Fig. 149. Positions of low velocity nozzle in cutting buttonhead rivets.**

rivet is reached, remove the head with one circumferential wiping movement, by pointing to the outside edge of the rivet hole in the outside sheet and following the circumference around, Fig. 149. This procedure will leave a ring of metal, the outside edge of the rivet, which falls away.

In following these procedures it is very important to start below the center of the head as this will allow the slag to run down or out from below and leave the metal being oxidized free from slag.

*Rivet Cutting with Standard Nozzle.* Where the low-velocity nozzle is not available, buttonhead rivets can be cut off by using a standard nozzle as follows (see also Fig. 150):

1. Use the size nozzle and oxygen pressure recommended for cutting steel 1 in. thick.
2. Holding the nozzle parallel with the sheet, cut a slot in the rivet head from the top of the button to the under side of the head, similar to the screwdriver slot in a round head screw.

3. As the cut nears the plate, draw the nozzle back at least $1\frac{1}{2}$ in. from the rivet. This is important.
4. When the slot just reaches the plate, swing the nozzle through a small arc. This slices off half of the rivet head.
5. Immediately swing the nozzle in the opposite direction. This takes off the other half of the rivet head.

By the time the slot is cut, the entire head will be preheated to a cutting temperature. While the bottom of the slot is being reached and just before cutting starts at the surface of the plate, the nozzle must be drawn back from the rivet a distance of about $1\frac{1}{2}$ in. or even more. This permits the oxygen to

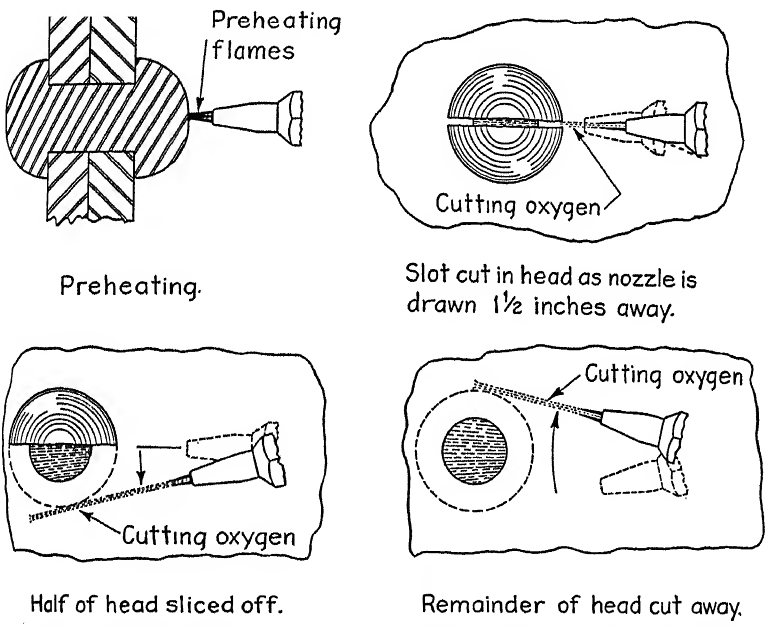



Fig. 150. **Manipulation of standard cutting nozzle in removing head of rivet.**

scatter slightly before it strikes the rivet, and prevents the jet from breaking through the layer of scale that is always present between the rivet head and the plate. As a result, the button drops off flush without damaging the base metal. If the nozzle is not drawn away, the force of the oxygen jet may pierce the film of scale.

## CUTTING PIPE

The cutting blowpipe is an indispensable adjunct to the welding blowpipe in the fabrication of oxwelded piping systems, see Chapter 16. With it, pipe can be quickly cut and beveled, for line joints, for branch connections and for the fabrication of welded fittings.

*Square Cut.* The simplest pipe cutting operation is to make a square cut as in preparation for a line joint.

Chalk or center-punch a line around the pipe at the point of cut. Start the cut at the top center of the pipe and carry the cut down one side to the bottom center line. As the cut progresses turn the blowpipe so that the nozzle points constantly at the interior center line or axis of the pipe. Then start the cut again at the top and carry it down the other side to complete the cut.

Where the amount of cutting warrants, it is convenient to rig up a set of rollers so that the pipe can be turned by a helper. In this way cutting is constantly done in the most convenient position at the top of the pipe.

*Beveling.* The beveling of pipe ends affords excellent practice in free-hand control of the cutting blowpipe. The blowpipe nozzle is simply held at an angle so that it will cut off the pipe end at the proper angle of bevel.

The beveling of openings for branch connections and of the ends of branch connections is slightly more complicated as the angle of bevel changes constantly so as to provide a satisfactory vee for welding.

*Radial Cutting.* In cutting openings in pipe for branch or header connections, radial cutting is used prior to beveling. Radial cutting, while easy of accomplishment once the idea is grasped, is rather difficult to describe in words, although a simple demonstration by an experienced operator will immediately make the operation clear. It means simply that the cutting nozzle is held in a line perpendicular to the interior center line of the pipe or radial to the surface of the pipe at every point of the cut. The cut edge is therefore square with the pipe wall at every point.

For pipe with a wall thickness of $\frac{3}{16}$ in. or more, the radial

cut is followed by a separate beveling cut in order to form a good vee for welding at all points.

## CUTTING MODERATELY HEAVY STEEL PLATE

In cutting heavier steel plate more attention must be paid to preheating and to careful regulation of the speed with which the cut is made. A piece of plate, 1 or 1½ in. thick, makes excellent practice material. Mark a line across one end of the plate and heat one end of this line to a bright red as before. Be sure that the spot is thoroughly heated before opening the cutting valve. When the cut has started, watch the jet of sparks that falls from the underside of the plate. If this should stop and shoot out horizontally for a time, it means that the cut has ceased to penetrate clear through the plate. It will be found that more skill is required to keep the cut going steadily in this heavier plate.

Fig. 151. Cutting a large I-beam.

The,cutting of extremely thick pieces of steel or iron is such a special problem that it is discussed separately in Chapter 38.

## PRECAUTIONS

In all cutting operations, special care should be taken to make certain that the hot slag does not come in contact with any combustible material. As the globules of hot slag may roll along the floor for considerable distances, any combustible material in the vicinity of cutting operations should, if possible, be moved a safe distance away, say 30 or 40 ft. If this can not be done, and if the work can not be moved to a more

suitable location, use sheet metal guards or asbestos blankets to protect the combustible material. Acetylene cylinders should always be placed far enough from cutting work so that there will be no possibility of hot slag falling on them. Study Recommendations J-18 and J-20 to J-22 in Chapter 40, pages 309 to 311.

Where cutting has to be done on painted metal, the operator should be provided with a suitable mask that will supply him with fresh air uncontaminated by lead fumes from the paint. See Recommendation J-17, page 309.

## CHAPTER 37

# Special Cutting Techniques

SPECIAL cutting techniques have been developed for certain metals that are less readily cut than the plain carbon steels. These include cast iron and stainless steel. Heavy sections of cast iron are best cut by means of the oxygen lance, page 286.

### CUTTING CAST IRON

The technique for cutting cast iron differs from that for steel in that much greater preheat is required and the cutting nozzle is oscillated constantly across the line of cut. The oxygen pressure required is from 25 to 100 per cent greater than for cutting steel of the same thickness. The heating flames should also be adjusted so as to have an excess of acetylene.

There are also decided differences in the quality of the various cast irons that cause variations in the ease with which they may be cut. Good quality gray iron includes castings which have been machined or are to be machined, and other castings known in foundries as "good gray iron castings." Poor grade cast iron includes castings such as ingot molds, grate bars and other castings that have been exposed to considerable heat, and also chilled iron, balance weights, floor plates and other castings known in foundries as "furnace iron" or "low grade castings."

*Cutting Technique.* Procedure for cutting good grades of cast iron is as follows:

(1) Adjust oxygen cutting regulator to give the correct pressure for the thickness of the cut. Make this adjustment with the blowpipe cutting valve open. Then close the cutting valve.

(2) Light the blowpipe. With the cutting valve open, adjust the heating flames with an excess of acetylene. The length of the excess acetylene "feather" should be approximately 2 to 2½ times the length of the inner cone.

(3) Close the oxygen cutting valve. Then begin with a

preliminary preheating with the blowpipe along the edge to be cut, from top to bottom. That is, preheat what will be the first "bite" of the cutting blowpipe through the entire thickness of the metal. By warming this part of the casting the cut will

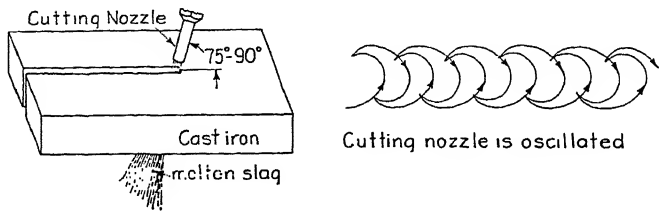



Fig. 152. Cast iron cutting technique.

start quicker and more easily. In general, the warmer the whole mass of iron, the easier it will be to cut.

(4) After this is done, hold the blowpipe so that the nozzle inclines at an angle of 75 deg. away from the edge of the casting to be cut.

The inner cones of the flame (not the excess cones) should be ⅛ to ¼ in. above the surface.

Give the nozzle a swinging motion describing semicircles across the line of cut.

Heat a semicircular area about ½ to ¾ in. in diameter until the metal is actually molten. When the metal begins to "boil", open cutting valve for an instant to blow off the slag.

(5) Move the nozzle just off the heated edge, open the cutting valve quickly, and then move the blowpipe along the line of cut, with the nozzle now at an angle of 45 deg. to the surface, Fig. 153. Use the same swinging motion described in paragraph 4. Keep the metal hot.

(6) As the cut progresses, gradually straighten up the blowpipe until it is at an angle of about 75 deg. (still pointed backward) when the cutting is well under way. On heavy material the metal will be sufficiently preheated by the cutting reaction and the cut should go forward regularly.

The blowpipe is swung from side to side, describing semicircles across the line of cut for the entire length. The diameter of these semicircles will depend upon the thickness and quality of the metal and upon the proficiency of the operator.

As the operator becomes experienced with this work he will be able to reduce the diameter of swing, and therefore the width of kerf.

(7) As the cut progresses, it may be possible to bring the blowpipe up almost to a vertical position. This should not be done, however, at the expense of losing the cut. There will always be considerable lag even if the blowpipe is straightened up to 90 deg.

Fig. 153. Starting a cut in cast iron.

(8) When the far edge is reached, carry the blowpipe over the edge and downward across the outer surface. Hold the blowpipe at about the angle of the lag. In this way the lag section can be cut through.

If the cut should be lost, move the blowpipe nozzle back along one edge of the kerf about ½ in. and describe semicircles, lapping that edge and the point where the cut stopped. If the cut is not readily resumed, carry the semicircles around to include both edges of the cut and the point where the cut stopped.

Flux cutting (see page 282) can be used to advantage in starting the cut. Simply feed in a ¼ or 5/16 in. steel welding rod. The cutting slag from this steel rod will help to start the cut.

*Cutting Thin Sections.* For material up to 1¼ to 2 in. thick, the cutting heat must be maintained through use of more clearly defined steps. Start the cut as described in paragraphs 4 and 5. If the top surface goes dark, or when the limit of the preheated section is reached, advance the nozzle about ¼ in., preheat another semicircular area, and again cut off the molten surface just as in starting the cut. Then quickly move the blowpipe backward a little, tilting the flame downward in a

more vertical direction to cut through the lower section. Then hold it steady for a moment to heat the upper surface again. As long as the cut continues to progress and the metal under the flame remains bright, keep going, disregarding the separate steps.

*Cutting Poor Grade Castings.* When a piece of cast iron is encountered that does not cut readily, follow the instructions given above except that the blowpipe nozzle should advance more slowly, describing semicircles about 1¼ to 1½ in. wide across the line of cut. The blowpipe should be held at an angle of about 75 deg. pointed backward when the work is progressing satisfactorily.

Fig. 154. Cutting a large cast iron crusher bowl.

Flux cutting (see pages 282 and 283) will also aid. Feed into the cut a ¼ or 5/16 in. steel welding rod as necessary to keep the cut going smoothly.

*Cutting Heavy Sections.* Heavy sections of cast iron are cut most effectively by using the oxygen lance and cutting blowpipe together as described on page 288.

*Protection of Operator.* Remember that cast iron cutting is a much hotter job than cutting steel. Sparks and slag come off in a much greater abundance. Always wear heavy asbestos gloves and suitable woolen clothing to protect body, face and head. Be sure also to protect your legs and feet well from the spattering of the melted slag. It is a good plan to use a firebrick as a hand rest. It will then be easier to control movements of the blowpipe.

Always make ample provision against heat and sparks before starting work so it will not be necessary to stop cutting to take shelter or provide further protection. Hot metal cuts best, so don't delay and allow the work to cool.

## CUTTING STAINLESS STEEL RISERS

A somewhat different technique has been found most satisfactory for cutting risers on chrome-nickel steel castings, particularly those of the type known as 18-8 stainless steel.

For this work an injector type blowpipe should be used. The nozzle should provide heating flames 50 to 100 per cent greater than for cutting plain carbon steel. Oxygen pressure should be 15 to 20 per cent more than for ordinary carbon steel of the same thickness.

The casting should be placed so that the cut can be started horizontally along the top of the line of cut.

Light the blowpipe and, with the cutting valve open, adjust the heating flame so as to have a very slight excess of acetylene. Avoid a heavily carburizing flame as this would be detrimental.

From Fig. 155, it will be evident that the cut is started horizontally across the top surface of the riser and that it

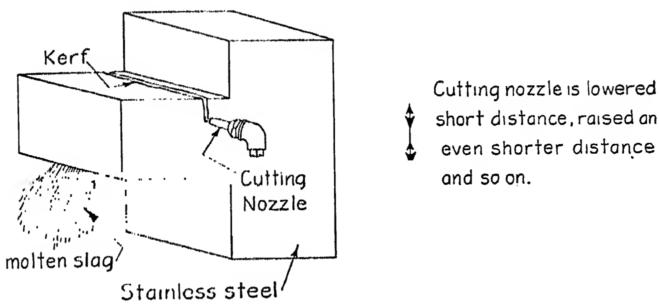



**Fig. 155. Stainless steel cutting technique.**

progresses downward in a vertical plane from the upper surface to the lower. During the cutting, the blowpipe is moved up and down.

In starting the cut, first preheat the top of the riser across what is going to be the line of cut. It is necessary to do this in order to establish a straight and easy kerf. When the line of cut has been preheated to a dull red, concentrate the preheat at the point where cutting will start. Very quickly the spot will become white and start to melt. With the blowpipe tip directed in a horizontal plane across the top, move the blow-

pipe so that the inner cones of the heating flames are about $\frac{3}{16}$ in. away from the face of the riser and turn on the cutting oxygen. If the preheating has been sufficient, the cut will start and it will be possible to look right into the whole of the kerf and watch the progress. The slag will be much more incandescent than is the case with plain steel, and will crackle and spark violently. With the cut properly started, proceed with gentle but speedy up and down motions to carry the cut through the riser.

It will be observed that the cut is not always sustained at the point directly in front of the blowpipe tip. Do not stop because of this refractory spot as it will be found that this point will be cut as the work progresses. As experience is gained, the distance between the blowpipe tip and the face of the riser will be varied unconsciously to take care of this refractory spot.

If cutting is stopped and the metal cools off below red, it will be found somewhat difficult to restart the cut readily, due undoubtedly to the fact that there is now a surface layer of slag added to the kerf.

A skilled operator will sever a 6x6-in. chrome-nickel steel riser in 3 to 3½ min. cutting time. The kerf made in this cutting is about one-third wider than that of carbon steel of same thickness. But the cut surface will, of course, not be as smooth as in plain carbon steel work, because of the need for hand movement in cutting.

The cutting of chrome-nickel risers should be done prior to any heat-treatment given the casting.

## FLUX CUTTING

With metals of low cutability, the slag formed usually does not flow freely. The cutting of such materials can frequently be facilitated by increasing the fluidity of the slag by mixing it with slag from a metal of high cutability or by the addition of certain substances that will produce the same result. This is called flux cutting.

Thus, feeding a steel welding rod or an iron bar into the cut will frequently make it easier to cut such materials as poor grade cast iron or risers on high chrome castings.

In certain cases, particularly in cutting furnace spills, the

addition of aluminum shot or of ferrosilicon has been found effective in increasing the fluidity of the slag and thus making cutting easier.

Another type of flux cutting is employed in cutting 18-8 chrome-nickel plate. The alloy plate is placed between two plates of plain carbon steel. The use of these cover plates also gives sharper corners on the cut edge of the 18-8 plate than would otherwise be possible in cutting this metal of relatively low cutability.

CHAPTER 38

# Manual Cutting of Heavy Sections

EVEN after considerable experience in cutting metals with the oxy-acetylene blowpipe, it is difficult to realize that the operation is not one requiring mechanical force or great physical effort. This is particularly noticeable when an operator attempts to cut material much heavier than that to which he is accustomed. There is an almost universal tendency to use an unnecessarily high oxygen pressure, acting apparently on the theory that high pressure is necessary for heavy cutting.

This mistake, which is a very natural one to make, is probably the most frequent cause of trouble in attempting to cut heavy sections with the blowpipe. The oxy-acetylene cutting process depends simply upon the chemical reaction between oxygen and red-hot iron or steel. Sufficient oxygen must be supplied to keep the cutting action going properly, but an excess may interfere with the action just as too much draught will blow out a fire.

*Use Correct Pressure.* When an inexperienced operator first attempts a cut on steel, say 10 in. thick, the natural tendency is to use a high oxygen pressure, considerably in excess of that recommended by the blowpipe manufacturer. With this pressure the cut will start all right at the corner but soon will penetrate only about three-quarters of the way through the metal. After a while, the cut will stop and examination will show a rounded cavity at the bottom of the cut.

This cavity is not, as many have thought, a blowhole in the metal, but it has been formed entirely by the excess oxygen. The mixture of hot slag and metal in the cut is actually cooled by this excess oxygen so that the cut is slowed down. This causes a swirling action at the bottom of the cut which soon hollows out a cavity.

Some reduction of the oxygen pressure will result in an im-

provement, but the cut will still be unsatisfactory. The kerf will tend to flare out at the bottom where it may be an inch or more in width.

Further reduction of the oxygen pressure to that recommended by the blowpipe manufacturer will result in a perfect cut. A smooth kerf about ⅜ in. wide at the top tapering to about ¼ in. at the bottom can then be made. The secret of heavy cutting is to use the pressures recommended by the blowpipe manufacturer. It is also essential to use oxygen hose of ample capacity and to make certain that there are no restrictions in the oxygen supply system that might interfere with supplying the proper amount of oxygen to the blowpipe.

Fig. 156. Removing risers from large steel casting.

*Cutting Holes.* In cutting holes in thick sections with the blowpipe, first mark the outline of the hole with chalk or centerpunch. Hold the blowpipe at a point about ½ in. inside the outlined area, so the cut will start in the section that is to be cut away. Heat the surface at this point almost to melting. Then gradually press down the cutting lever and at the same time advance the blowpipe with the nozzle perpendicular to the surface, tracing a line about ½ in. from the finish line. Regulate the advance of the blowpipe and the rate at which the cutting valve lever is depressed so when the blowpipe has advanced about 2 in. the cut will have penetrated the entire thickness and the cutting valve will be open full. Then advance the blowpipe steadily along the finish line and end by cleaning off the narrow section near the point of starting.

*Cutting Large Rounds.* To start a cut on a round bar or shaft, where there is no corner to begin on, first make a deep nick with chisel and sledge. This will give a thin edge or corner on which the cut can be started easily.

*Heaviest Cuts.* There is, of course, a limit to the thickness

of metal that can be cut with the blowpipe alone. For the average skilled operator the limit is probably 18 or 20 in. More experienced operators are able to make even heavier cuts.

Steel and iron of practically unlimited thickness can be cut by means of a device known as an oxygen lance used either alone or in conjunction with a cutting blowpipe. Masses of steel up to 8 ft. in thickness have been severed in this way.

## OXYGEN LANCE

An oxygen lance consists essentially of a length of steel pipe connected through an oxygen hose to a regulated supply of oxygen. In setting up an oxygen lance, at least two cylinders of oxygen should be connected with a properly designed manifold, and the flow of oxygen should be controlled by a manifold regulator which is designed to pass the large volumes of oxygen required by the lance. For connecting the regulator to the lance, it is preferable to use 3/8-in. oxygen hose. Pneumatic hose or fittings should never be used as there is always the possibility that a piece of oily or greasy hose may be used. A piece of 1 in. extra heavy steel pipe about 3 ft. long and bent 90 deg. is then connected to the oxygen hose through a reducing coupling and standard oxygen hose connection. This pipe serves as a handle for the lance, permitting the operator to work at one side out of the direct line of sparks and slag produced in the operation.

The lance pipe is connected to the other end of this 1 in. pipe by means of a reducing coupling. For moderately heavy work, 1/8-in. steel pipe may be used for the lance, and even the heaviest work will not require more than 1/4-in. pipe. The lance pipe should have ends with easy working threads as it is usually necessary to insert new lengths of pipe during the cutting operation. Each length should be provided with the usual threaded sleeve. All pipe used must be free from oil and grease. Probably the most satisfactory method for removing oil and grease from new pipe is to heat it red-hot, thus burning or charring all combustible material. As the pipe is consumed in the lance operation, a sufficient number of lengths should be provided so that the cut can be completed without delay.

*Starting the Lance.* In operation the oxygen lance differs from the cutting blowpipe in that there are no heating flames to maintain the material at the kindling point. It also differs from the cutting blowpipe in that once cutting has started the lance pipe itself burns and furnishes the heat necessary to keep the cut going. In order to start the oxygen lance, it is necessary to heat a spot on the metal to be cut. This may be done in any one of a number of ways. If a cutting or welding blowpipe is handy, this furnishes the easiest way of heating the metal. Other methods are to place a red-hot rivet or a shovelful of red-hot coals on the spot, or to heat the end of the lance pipe in a fire until red-hot, then when a small stream of oxygen is allowed to pass through the pipe, the red-hot end will burn brilliantly, giving sufficient heat to start the cut when the lance is brought in contact with the metal to be cut.

*Pressure Required.* In using the oxygen lance it is desirable to have two workmen, one to operate the lance and the other to control the oxygen pressure at the manifold regulator. In

Fig. 157. The oxygen lance quickly pierces a hole through the center of a 30-in. length of chrome-nickel steel shafting.

starting the lance only a few pounds pressure is necessary; this is increased as the lance penetrates the metal, the final pressure depending largely on the thickness of the material cut and also to a certain extent on the composition of the metal. Thus the maximum pressure is about 75 lb. per sq. in. for medium carbon or machinery steel containing up to 0.50 per cent carbon, and about 100 lb. per sq. in. for low carbon or

mild steel. If the job is very heavy, a third workman may be required to change oxygen cylinders and lance pipe.

*Piercing Holes.* Used alone, the oxygen lance is particularly effective in piercing holes. See Fig. 157. Its piercing action is very rapid, not more than two minutes' actual cutting time being required to sink a hole 2½ in. in diameter 1 ft. deep into a hard mass of iron or steel. This property of the oxygen lance makes it of the utmost value in routine and emergency tapping of blast furnaces, open hearth furnaces, in opening frozen stoppers on steel ladles, and in drilling holes in salamanders, spills and ladle skulls so that they can be blasted. The details of this work are beyond the scope of the present article, but complete information will be found in a booklet "The Oxygen Lance." *

*Modified Lance.* For piercing small holes accurately, a modified form of oxygen lance is very useful. The oxygen hose leading from the cutting regulator is attached to the Oxweld Type L-4 carbon burning blowpipe handle. As the sleeve coupling for ⅛-in. steel pipe will fit on the exit nozzle of this blowpipe, a half length of ⅛-in. pipe is used to form the lance. The valve on the blowpipe handle enables the operator to control the flow of oxygen very exactly. This modified lance may be used advantageously to pierce small holes very accurately through metal up to about 24 in. in thickness.

## HEAVY CUTTING WITH LANCE AND BLOWPIPE

For cutting extemely heavy material, an oxygen lance and cutting blowpipe are used together. The blowpipe furnishes the heat necessary to keep the cut going along the top surface and the lance carries the cut through to the bottom of the section. See Fig. 158.

*Arrangement of Work.* Careful consideration should be given to the arrangement of the work before cutting is done. It is most important to provide for the free flow of cutting slag out of the bottom of the kerf. Wherever possible, heavy sections should be supported so as to give a clearance of at least 8 to 12 in. underneath.

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* Published by The Linde Air Products Company.

*Cutting Procedure.* The procedure for cutting heavy material by this method is as follows: The operator, using the cutting blowpipe fitted with the largest size nozzle, starts the cut at one side. The cut will soon penetrate from 4 to 8 in. into the steel mass, and as the blowpipe advances 2 or 3 in. along the line of cut, a steady stream of white hot slag will start dropping from the bottom of the cut. At this point an oxygen lance of ¼-in. pipe is brought into action. The oxygen pressure for the lance depends on the variety of steel—75 lb. per sq. in. for medium carbon or machinery steel, and 100 lb. per sq. in. for low carbon or mild steel. The oxygen lance starts rapidly on the hot slag delivered by the cutting blowpipe and carries the cut to the bottom of the section. The lance is then raised to a starting position and again lowered, removing another layer of metal as it descends. The action of the lance is thus somewhat like that of a cross-cut saw.

Fig. 158. The oxygen lance and cutting blowpipe working together will sever large masses of steel rapidly and economically.

It is sometimes possible to dispense with the blowpipe entirely after the lance has had a good start. However, this is possible only where due consideration has been given to the arrangement of the part to be cut.

## USE OF TWO LANCES

Heavy cuts can also be made by using two lances together. Fig. 159 shows this method being used to remove a hot top 24 in. thick and 66 in. wide from a nickel steel ingot. The second lance was used to carry off the slag from the bottom of the cut

and in this way speeded the cutting considerably and actually lessened the oxygen consumption. Only 15 min. was required to remove this hot top and 120 ingots of this type were cut in the same way.

Fig. 159. Two oxygen lances remove the hot top from an alloy steel ingot 24 in. thick and 66 in. in width.

## PROTECTION OF OPERATORS

It will be observed in Fig. 159 that a cover or shield has been placed over the top of the ingot at the left of the cut. This is to protect the operators from the heat radiated from the hot metal, as this ingot was cut while it was at a temperature of about 1,500 deg. F.

Shields should also be provided wherever necessary to protect operators from streams of cutting slag. This is particularly important when the lance is being used to pierce holes horizontally. A typical shield arrangement is shown in Fig. 157.

CHAPTER 39

# Machine Flame Cutting

AS compared with manual flame cutting, the guidance of the oxy-acetylene cutting blowpipe by some mechanical means results in better workmanship, greater accuracy and lower cost. The cutting operation is greatly simplified as the operator is freed from the actual handling of the blowpipe.

Many types of cutting machines are now available. They may be classified in various ways, according to whether they are manually operated or motor-driven; partly or almost fully automatic; portable or stationary.

Cutting machines in which the movement of blowpipe is actuated by a manually operated mechanism include types for cutting and beveling pipe. The simplest motor-driven machine is one designed to produce only straight-line cuts either with or without beveled edges.

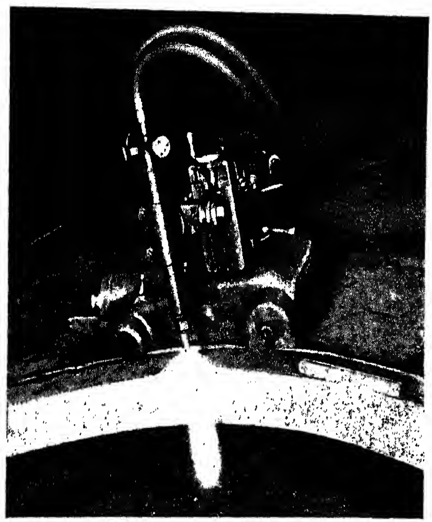


Fig. 160. Portable oxy-acetylene cutting machine performs the difficult operation of trimming the edges of heavy curved plate.

Portable, self-propelling machines which run on sections of straight track or on the surface of material being cut, provide an exceedingly flexible means of doing a wide range of cutting. Such machines can handle automatic straight line cutting, straight bevel cutting, circle or ring cutting and the cutting of curved or irregular shaped pieces. These machines can climb moderate grades and can

thus cut curved or warped plate—an operation that is practically impossible by any other means. See Fig. 160.

Maximum productive capacity is reached in the stationary, practically automatic type of cutting machine developed for production cutting of regular or irregular shapes from steel sections. It is particularly adapted where the same pattern

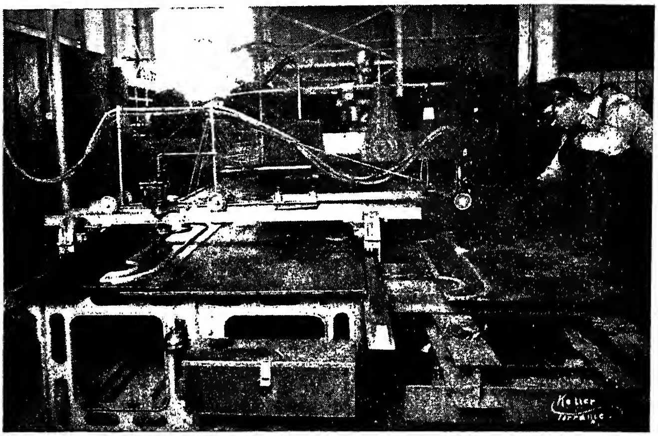


Fig. 161. Oxy-acetylene shape cutting machine. The templet at the left automatically guides the cutting blowpipe.

or design is to be cut repeatedly, in which case a templet is used to guide the carriage so that the blowpipe moves automatically along the line of cut. See Fig. 161.

## OPERATING PRINCIPLES

In order to obtain the best results with any type of cutting machine, the instructions furnished by the manufacturer should be followed carefully.

*Oxygen and Acetylene Supply.* Arrangements should be made to supply the cutting machine with a sufficient amount of oxygen and acetylene so that cutting can proceed without interruption. The larger stationary machines are usually supplied with oxygen piped from a centrally located oxygen manifold, preferably of the duplex type; and with acetylene piped from an acetylene generator or an acetylene cylinder manifold. Portable oxygen and acetylene cylinder manifolds

can be used to supply portable cutting machines operating outside the shop or in shops where work is done in a number of widely separated places so that permanent distribution lines would not be practical.

*Arrangement of Work.* Before starting to cut, consideration must be given to the arrangement of the work in relation to the cutting machine. In the case of shape cutting machines, for example, the work must be leveled on the work-supporting table and so positioned that the piece can be cut properly at

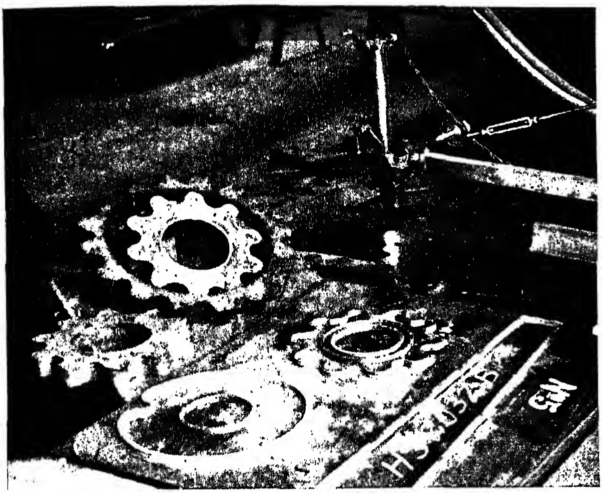


Fig. 162. These sprockets are typical of the intricate shapes that can be produced in any quantity desired.

all points. The relative positions of templet and work should also be checked in advance. This can be done by moving the machine by hand along the templet to make certain that the blowpipe will always move within the area of the piece to be cut.

*Cutting Speed and Oxygen Pressure.* For any given thickness of metal, there is in general a certain combination of cutting speed and oxygen pressure which will give the most satisfactory cut, with complete penetration at all points and with minimum lag. The cutting speeds and oxygen pressures rec-

ommended by the manufacturer will serve as a guide but may require slight modification in specific cases.

The correct combination is particularly important in cutting heavy material. If the oxygen pressure is too high or the cutting speed too slow, the cut surface will be rough and the kerf will tend to widen out at the bottom of the cut. If the cutting speed is too great, the cut will not penetrate entirely

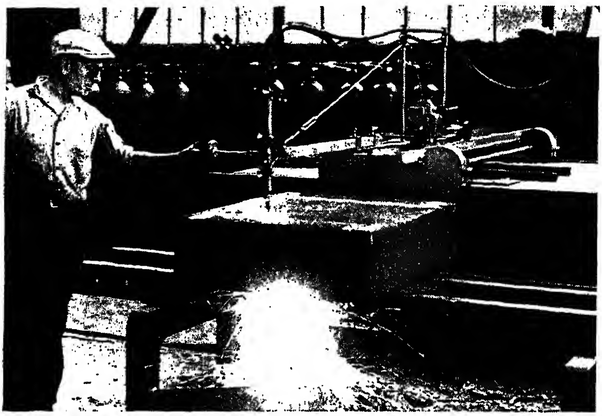


Fig. 163. Oxy-acetylene shape cutting has revolutionized the production of parts for heavy machinery.

through the material. With the correct combination the cut surface will be smooth and regular.

*Preheating.* Steels having a carbon content higher than 0.35 per cent should be preheated before cutting, for the reasons given in Chapter 35. A temperature of 500 to 600 deg. F. is usually adequate, although in some cases temperatures as high as 1,100 deg. F. may be preferable. Certain heat-treated steels should be heat-treated or normalized after cutting in accordance with recommendations of the cutting machine manufacturer.

*Cutting Procedure.* The actual cutting procedure in machine flame cutting is relatively simple. To start a cut at the edge of the material, the blowpipe is placed so that the heating flames are 1/16 to 1/8 in. above the surface just at the edge. When this spot has been heated to a bright red, the cutting oxygen valve is opened and the machine started simultaneously.

The correct oxygen pressure and cutting speed are set in advance. The cut should then continue without interruption to the end.

To start a cut away from the edge, a starting hole is first pierced by the blowpipe at a spot slightly off the line of cut and in metal that will be scrapped. The cut is started at this hole and then brought in to the line of cut.

## CHAPTER 40

# Precautions and Safe Practices

In the Storage, Care and Handling of Oxy-Acetylene Welding and Cutting Equipment

### A. *Oxygen and Acetylene Cylinders*

A-1. All oxygen and acetylene cylinders carrying I.C.C. markings are manufactured under close inspection, are provided with proper safety devices, and are given most severe tests, as required by specifications established by the Interstate Commerce Commission. But proper construction does not eliminate the necessity of preventing their abuse.

All cylinders should carry markings to show they comply with the regulations of the Interstate Commerce Commission: Oxygen, I.C.C. 3A; Acetylene, I.C.C. 8. No other cylinders should be used for oxy-acetylene service.

STORAGE

A-2. Comply with all regulations of the National Board of Fire Underwriters and with local, state and municipal regulations relative to the storage of oxygen cylinders.

A-3. Cylinders stored inside buildings should be kept away from radiators and other sources of heat.

A-4. Cylinders should be stored in definitely assigned places where they will not be liable to be knocked over or damaged by passing or falling objects.

A-5. Inside buildings, cylinders of oxygen should not be placed in the same compartment with cylinders of acetylene or other fuel gas; there should be a fire-resisting partition between the oxygen cylinders and acetylene or fuel gas cylinders.

A-6. Where cylinders are stored in the open, they should be protected from accumulations of ice and snow

and from the direct rays of the sun, and cylinders containing one gas should be placed well away from cylinders containing another gas.

A-7. Full cylinders and drums of calcium carbide should be used in rotation as received from the supplier.

HANDLING

A-8. When transporting cylinders by a crane or derrick, use a cradle, boat, or suitable platform. Never use slings or an electric magnet. Valve protecting caps must always be in place. Never lift a cylinder by means of the valve protecting cap.

A-9. Suitable trucks should be provided for conveying and handling cylinders.

A-10. A suitable truck, chain or steadying device should be used to keep cylinders from being knocked over while in use.

A-11. Unless cylinders are on a suitable truck, regulators should be removed when the outfit is moved.

A-12. Cylinders should be kept far enough away from the actual welding or cutting operation so that sparks, hot slag or flame will not reach them.

CLOSE VALVES WHEN NOT IN USE

A-13. Close cylinder valves before moving cylinders.

A-14. Always close cylinder valves when work is finished.

A-15. Always close valves of empty cylinders.

A-16. Never use cylinders as rollers or supports even if considered empty.

A-17. It is illegal to tamper with numbers and markings stamped into the cylinders.

A-18. Empty cylinders should be segregated from full cylinders and promptly returned to the supplier. When returning empty cylinders to the supplier by freight, forward the original bill of lading promptly. *Be sure all valves are closed.*

B. *Oxygen Cylinders*

B-1. *Keep oxygen cylinders and fittings away from oil or grease: Oil or grease in presence of oxygen under pressure may ignite violently.* Oily or greasy

substances must be kept away from cylinders, cylinder valves, couplings, regulators, hose and apparatus. Do not handle oxygen cylinders or apparatus with oily hands or gloves. Oxygen cylinders should never be handled on the same platform with oil or placed in a position where oil or grease from overhead cranes or belts is likely to fall upon them. A jet of oxygen should never strike an oily surface, greasy clothes or enter a fuel oil tank or storage tank that has contained a flammable substance.

B-2. Always refer to oxygen by its proper name—"*Oxygen*" —and not, for example, by the word "Air."

*Warning*

*A serious accident may easily result if oxygen is used as a substitute for compressed air. Never use oxygen in pneumatic tools, in oil preheating burners, to start internal combustion engines, to blow out pipe lines, to "dust" clothing or work, or for head pressure in a tank of any kind.*

STORAGE

B-3. Do not store reserve stocks of oxygen alongside of reserve supplies of acetylene or other fuel gas cylinders. (See Recommendations A-5 and A-6, page 296).

B-4. Do not store cylinders near highly combustible material, especially oil, grease, or any substance likely to cause or accelerate fire. Oxygen will not burn, but supports and accelerates combustion and will cause oil and other similar materials to burn with great intensity.

B-5. Do not store cylinders near furnaces or radiators. Cylinder valves are equipped with a safety device which acts as an excess pressure release. Excessive heat will increase the temperature of the oxygen and will cause a corresponding increase in the pressure within the cylinder. At abnormally high pressures the safety release blows or bursts, and the oxygen escapes to the air.

B-6. Do not drop oxygen cylinders or handle them roughly.

USE

B-7. Never use oxygen from a cylinder without first attaching an oxygen regulator to the cylinder valve.

B-8. Do not use a hammer or wrench to open oxygen cylinder valves. If valves cannot be opened by hand, notify the supplier.

B-9. *The cylinder valve should be opened slowly.* If the high pressure is suddenly released it is liable to damage the regulator and pressure gauges. Stand to one side of the regulator when opening the cylinder valve.

B-10. When the oxygen cylinder is in use the valve should be open to the full limit in order to prevent leakage around the valve stem.

B-11. Never tamper with nor attempt to repair oxygen cylinder valves. If trouble is experienced, send the supplier promptly a report on the character of the trouble, giving the serial number stamped on the cylinder. Follow his instructions as to its prompt return.

B-12. A suitable truck, chain or steadying device should be used to keep cylinders from being knocked over while in use or while being moved.

B-13. Do not move an oxygen cylinder from one job to another unless the valve is securely closed and the valve protecting cap is in place.

B-14. *Remember always—never allow oil or grease to come in contact with oxygen.* Never use oxygen as a substitute for compressed air, or as a source of pressure.

## C. *Acetylene Cylinders*

C-1. Call acetylene by its proper name—*"Acetylene"*— and not by the word "Gas." Acetylene is far different from city gas or furnace gas.

C-2. Acetylene is a fuel gas, and since it will burn, acetylene cylinders must be kept away from fire.

STORAGE

C-3. Acetylene cylinders should be stored and used with valve-end up, and not be allowed to lie on their sides.

C-4. Acetylene cylinders should be stored in a well-protected, ventilated, dry location, well away from highly combustible material such as oil or excelsior, and should not be stored near stoves, radiators or furnaces. The fusible safety plugs with which all cylinders are provided melt at about the boiling point of water, and for this reason, should the outlet valve become clogged with ice, thaw with warm, not boiling water, applied only to the valve. Never use a flame for this purpose.

## HANDLING

C-5. Acetylene cylinders should be handled carefully. Rough handling, knocks or falls are liable to damage the cylinder, valve or fuse plugs and cause leakage.

C-6. If when the valve on the acetylene cylinder is opened there is found to be a leak of acetylene around the valve spindle, close the spindle and tighten the gland nut around the spindle thus compressing the packing around the spindle. If this does not correct the trouble, discontinue the use of the cylinder and advise the supplier. In case the acetylene should leak from the cylinder valve and cannot be shut off with the spindle, remove the cylinder to the open, attach a regulator and then use the acetylene in the cylinder on work in progress. If rough handling should cause a leak at the fuse plugs safety device, remove the cylinder to an open place well away from any source of ignition, slightly open the cylinder valve and allow the acetylene to escape slowly. A warning should be placed near this cylinder not to approach it with a lighted cigarette or other source of ignition. Tag such a cylinder plainly, notify the supplier, and follow his instructions as to its return.

C-7. Never tamper with fuse plugs.

## USE

C-8. Never use acetylene from a cylinder without first attaching a pressure reducing regulator to the cylinder valve.

C-9. Always open the cylinder valve slowly.

C-10. Do not open an acetylene cylinder valve more than one and one-half turns of the spindle.

C-11. Always use the special T-wrench provided for the acetylene cylinder valve.

C-12. Leave this special wrench in position on the stem of the acetylene valve while cylinder is in use so that the acetylene can be quickly turned off in case of emergency. If this wrench is lost a new one may be obtained from the acetylene supplier.

C-13. Do not use the top of an acetylene cylinder as a receptacle for tools which may damage the safety devices in the head or interfere with the quick closing of the cylinder valve.

C-14. For a very heavy job, it may be necessary to couple two or more acetylene cylinders to supply a single blowpipe. Such coupling devices should be of a type recommended by The Linde Air Products Company. Do not supply acetylene from a cylinder or cylinders to a system of shop piping without consulting The Linde Air Products Company and following their directions.

C-15. Never under any circumstances attempt to transfer acetylene from one cylinder to another, nor to refill an acetylene cylinder, nor to mix any other gas with acetylene in a cylinder.

C-16. When returning empty cylinders to the original supplier by freight, or express, send the original bill of lading to them promptly. *Be sure to close the valves.*

## D. *Hose*

D-1. Only hose made specially for welding and cutting should be used. Oxygen hose should be green in color, and acetylene hose should be red in color. Oxygen hose and acetylene hose should not be interchanged. (Note: the ¼-in. and larger sizes of hose are usually branded "Oxygen" or "Acetylene".)

D-2. Pneumatic hose or hose fittings should not be used on welding and cutting equipment, because it is desirable to differentiate sharply at all times between "air" and "oxygen". If pneumatic fittings are used,

a piece of hose oily or greasy from previous use with air tools will sooner or later be used.

D-3. Do not use metal covered hose. It is not sufficiently flexible to permit proper handling of the welding blowpipe. If some combination of accidental causes should build up a bursting pressure in metal covered hose, the metal covering would fly into fragments.

D-4. New hose is dusted in the inside with fine talc; blow this dust out before using. The lengths of hose to be used can be attached to an oxygen supply adjusted to a pressure not exceeding 5 lb. per sq. in. When acetylene hose is so treated, before attaching it to the acetylene regulator blow through it from the mouth.

### TIGHT CONNECTIONS IMPORTANT

D-5. Only standard hose connections of the correct size should be used for connecting hose to blowpipes and regulators. It is very important that these connections be tight. Test for leakage with soapy water (use only Ivory soap) or spittle. Never use wire for binding hose to the hose nipple.

D-6. No white lead, oil or grease, or other pipe-fitting compounds should be used for making joints.

### PROTECTION AGAINST DAMAGE

D-7. Unnecessarily long lengths of hose should be avoided. When they must be used, care should be taken that the hose does not become kinked or tangled and that it is protected from damage.

D-8. Always protect hose from being trampled on or run over. Avoid tangles and kinks. Do not leave the hose so it can be tripped over as a connection may be pulled off, or, worse still, the cylinders and equipment may be pulled over.

D-9. Protect the hose from flying sparks, hot slag, hot objects, and open flame.

D-10. Do not allow hose to come in contact with oil or grease; these deteriorate the rubber and constitute a hazard with oxygen.

### INSPECTION AND REPAIR

D-11. Hose should be inspected periodically and kept in repair in accordance with the maintenance recommendations K-12 to K-15, pages 314 and 315.

## *Safe Practices in Setting-Up Welding and Cutting Apparatus*

### E. *To Connect Oxygen Regulator*

E-1. Be sure there is no oil or grease on hands or gloves.

E-2. Open the oxygen cylinder valve slightly for an instant, and then close it (this action is generally termed "cracking"). This will clear the valve of dust or dirt that otherwise might enter the regulator. When opening the valve of an oxygen cylinder, always stand to one side of the outlet.

E-3. Connect oxygen regulator (right hand connection) to oxygen cylinder valve. Tighten the nut with the wrench supplied with the regulator.

E-4. Never force connections which do not fit.

E-5. Be sure the union nut is pulled up tight to prevent leaks.

E-6. Never connect an oxygen regulator to a cylinder containing combustible gas, or *vice versa*.

E-7. Connect oxygen hose to outlet connection of the regulator. Be sure this connection is tight.

E-8. Make sure that the pressure adjusting screw of the regulator is released, that is, that it is turned counterclockwise (to the left) until it is loose, before opening the cylinder valve. Open the oxygen cylinder valve slightly so that the high pressure gauge hand moves up slowly. Never open the cylinder valve suddenly, as the rush of high pressure oxygen might strain the high pressure gauge mechanism. After the high pressure gauge hand has stopped moving, open oxygen cylinder valve fully.

E-9. Turn the pressure adjusting screw of the regulator clockwise (to the right) permitting oxygen to pass through the hose. Keep turning the handle until pressure of about 5 lb. per sq. in. shows on the small

or low pressure gauge. Then turn the pressure adjusting screw of the regulator to the left until the flow of oxygen stops. This will blow out dirt from the hose so that it will not be carried into the blowpipe when the hose is connected to it.

## F. *To Connect Acetylene Regulator*

F-1. Open the acetylene cylinder valve one-quarter of a turn and close immediately (this action is generally termed "cracking the valve"). This will blow out accumulations of dust in the valve. Never "crack" an acetylene cylinder valve near other welding work or near sparks, flame or any possible source of ignition.

F-2. Connect the acetylene regulator to the acetylene cylinder valve which is threaded left-hand and consequently the connection is made by turning counterclockwise. With some acetylene regulators, an adaptor has to be used in order to attach them to the cylinder valve. When this is the case first connect the adaptor to the cylinder valve and then connect the regulator to the adaptor.

F-3. Never force connections which do not fit.

F-4. Be sure that the connections between the regulators, adaptors and cylinder valves are tight. Test with soapy water or spittle. Escaping acetylene can generally be detected by smell.

F-5. Never connect an acetylene regulator to a cylinder containing oxygen, or *vice versa*.

F-6. Connect the acetylene hose to the outlet connection of the regulator. Be sure this connection is tight.

F-7. Make sure that the pressure adjusting screw of the regulator is released, that is, that it is turned counterclockwise (to the left) until it is loose, before opening the cylinder valve.

F-8. Open the acetylene cylinder valve slowly by means of the special T-wrench supplied for that purpose. This valve should not be opened more than one and one-half turns, and the wrench should be left in place during the work. The pressure in the acetylene cyl-

inder will then be shown on the high pressure or cylinder contents gauge which is sometimes larger in diameter than the working pressure gauge.

F-9. New acetylene hose should be blown out in accordance with Recommendation D-4, page 302. Where acetylene hose that has already been used is being connected up, it will be sufficient to blow through it from the mouth. Do not blow out the hose with acetylene.

## G. *Connecting the Blowpipe and Adjusting Pressure*

G-1. Connect the oxygen hose from the oxygen regulator to the hose connection on the blowpipe marked "Oxygen."

G-2. Connect the acetylene hose from the acetylene regulator to the hose connection on the blowpipe marked "Acetylene."

G-3. Select the proper welding head, tip or cutting nozzle (according to the chart or table furnished by the apparatus manufacturer) and screw it carefully and tightly into the blowpipe.

G-4. Open the blowpipe oxygen valve only. Adjust the oxygen regulator by turning the pressure adjusting screw to the right until the low pressure gauge indicates the proper pressure as given in the welding and cutting chart, while the blowpipe oxygen valve is open and oxygen passing through the head or tip. In the case of cutting blowpipes or cutting attachments, both the blowpipe oxygen valve and the cutting valve must be open while adjusting the oxygen pressure at the regulator. Then close the blowpipe oxygen valve.

G-5. The acetylene pressure should be adjusted as follows:

With a low pressure blowpipe operated from a low pressure acetylene generator, close the blowpipe acetylene valve and open the shut-off valve at the hydraulic back pressure valve.

With a low pressure blowpipe operated from an acetylene cylinder or a medium pressure acetylene generator, open the blowpipe acetylene valve two turns and turn the pressure adjusting screw on the acetylene

regulator to the right until the hand in the low pressure gauge barely leaves the pin. Then immediately close the blowpipe acetylene valve.

With a medium pressure blowpipe (or a low pressure cutting blowpipe equipped with a medium pressure mixer nozzle) operated from an acetylene cylinder or from a medium pressure acetylene generator, first close the blowpipe acetylene valve. Turn the pressure adjusting screw on the acetylene regulator to the right until the low pressure gauge indicates the proper pressure as given in the welding and cutting chart. Then open the blowpipe acetylene valve and, while acetylene is flowing through the blowpipe, readjust the pressure, if necessary, to exactly the proper pressure as given in the welding and cutting chart. Then immediately close the blowpipe acetylene valve.

## H. *To Light the Blowpipe*

H-1. In lighting the blowpipe and adjusting the flame, always follow exactly the manufacturer's directions for the particular model of blowpipe that is being used. This is necessary because the proper procedure varies somewhat with different types of blowpipes, and even with different models made by a single manufacturer.

H-2. Do not use matches for lighting blowpipes; hand burns may result. Use friction igniters, stationary pilot flames or some other suitable source of ignition. Do not light blowpipes from hot work in a pocket or small confined space.

H-3. In using welding and cutting equipment, observe the general operating recommendations, Section J.

## I. *To Shut Off the Blowpipe*

I-1. When the welding or cutting is finished, extinguish the flame by closing the acetylene valve and the oxygen valve at the blowpipe handle in order named.

I-2. When stopping work, observe the precautions given in J-23 and J-24, page 311.

## J. *General Operating Recommendations*

J-1. *Use no oil.* Never allow oil or grease of any kind to come in contact with oxygen. It constitutes a hazard. No lubrication of apparatus is necessary.

J-2. All oxy-acetylene operations should be under the supervision of trained and qualified men.

J-3. Never use acetylene at pressures in excess of 15 lb. per sq. in.; to do so is prohibited by all insurance authorities and by law in many places.

J-4. Do not experiment with or alter regulators or blowpipes in any way.

J-5. Always see that hose is securely attached to the blowpipe and regulators before using.

J-6. Always use the proper tip or nozzle and the proper pressure for the work involved, as shown on the apparatus manufacturer's pressure chart.

J-7. Always wear goggles when working with a lighted blowpipe. Use only goggles that are supplied by reputable manufacturers who understand the needs of the welding industry.

J-8. Do not hang a blowpipe with its hose on regulators or cylinder valves.

J-9. Be sure that space between cylinders and the job is clear so that valves can be reached quickly in case of emergency.

### CHANGING CYLINDERS

J-10. When a cylinder is to be changed, first close the cylinder valve and then open the blowpipe valve to release the pressure in the regulator. Then release regulator pressure adjusting screw by turning it to the left and disconnect the regulator with the wrench provided. Crack the valve of the new cylinder, and follow the recommendations in Sections E, F and G in attaching the regulator and adjusting the pressure.

J-11. When a new cylinder is connected to apparatus, always open the cylinder valve, the blowpipe valve and regulator for a short time to expel any air from the hose before lighting the blowpipe.

## BACKFIRE AND FLASHBACK

J-12. Improper handling of the blowpipe may cause the flame to backfire, or very rarely, to flashback. Should the flame backfire—go out with a loud snap or pop—it can be relighted instantly if the metal being welded is hot enough to ignite the gases, otherwise a lighter should be used. A backfire may be caused by touching the tip against the work, by overheating the tip, by operating the blowpipe at other than recommended gas pressures, by a loose tip or head, or by dirt on the seat.

J-13. Should the flame flashback—burn back inside the blowpipe—immediately shut off the blowpipe oxygen valve which controls the flame, then close the acetylene valve. After a moment, relight blowpipe in the usual manner. Even with improper handling of a blowpipe, a flashback will rarely occur. When one happens, it indicates that something is radically wrong with the blowpipe or the manner of operating it. In order to prevent flashbacks, delivery pressure of both gases should be maintained at the proper figure. By doing this flashbacks will be eliminated to a great extent.

## VENTILATION

J-14. When working in a confined space, be sure of proper and adequate ventilation, by natural means or by an air fan or blower. Never feed oxygen from a cylinder into a confined space. It is unsafe to do so. Welding or cutting in confined spaces is a job requiring special precautions. The operator should wear special clothing—preferably fireproofed, but certainly of wool.

J-15. When working in a confined space, always have a helper present outside of the confined space to close the cylinder valves or help in other cases of emergency. Test all equipment for leaks before taking it into such places, and bring it out with you when work is interrupted for any reason.

J-16. Welding on brass, bronze or galvanized iron should be conducted in well ventilated locations and oper-

ators should be supplied with suitable respirators to prevent the inhalation of zinc fumes, particularly if the welding job is of any considerable duration. In the event of the workman experiencing any nausea after a while or after he has been welding brass, bronze or galvanized iron, he should drink milk copiously.

J-17. Where flame cutting has to be done on metal that has been surface coated with lead paint, the operator should be provided with a gas mask which will supply him fresh air uncontaminated with lead fumes.

### SPECIAL PRECAUTIONS

J-18. Never do any welding or cutting on used drums, barrels, tanks or other containers until they have been cleaned so thoroughly as to make absolutely certain that no flammable materials are present. Where steam is available, this may be used to remove materials which are easily volatile. Washing with strong caustic soda solution will remove heavier oils. Even after thorough cleansing, the container should wherever possible be filled with water before any welding, cutting or other hot work operation is performed. In practically every case it will be found possible to place the container in such a position that it can be kept filled with water to within a few inches of the point where welding or cutting is to be done. In doing this, care should be taken to make sure that there is a vent or opening to provide for the release of heated air from inside the container. This can usually be done by opening the bung, hand hole or other fitting which is above the water level.

Where alterations or repairs are being carried out on large containers that have held flammable substances, periodic examination of the air contents of the vessels should be made from time to time wherever possible, by means of a gas detector where such an instrument is available. Although the vessel may have been steamed and flushed with soda there may still be traces of oil or grease under seams and the heat of the welding or cutting operations may cause such oil or

grease to give off flammable vapor to the extent that an explosive mixture may be formed inside of the tank. If possible, keep a supply of carbon dioxide in the vessels while under the process of repair. The use of carbon tetrachloride for this purpose is not recommended as carbon tetrachloride gives off a poisonous vapor when heated.

J-19. Never attempt to weld a jacketed vessel, tank or container until after every possible precaution has been taken to vent the confined air sufficiently. A metal part which is suspiciously light is hollow inside, and should be drilled before heating. Otherwise it will act like a bomb.

J-20. Do not cut material in such a position as will permit sparks, hot metal, or the severed section to fall on the cylinder, hose, legs or feet.

J-21. Where welding or cutting has to be done in the vicinity of combustible material, special precautions should be taken to make certain that sparks or hot slag from the welding or cutting operations do not reach combustible material and thus start a fire.

Cutting or welding work which can be transported should be removed to a safe location in a sprinklered or non-combustible building. If the work cannot be moved, exposed combustible material should if possible be moved a safe distance away, say thirty or forty feet. Wherever there are floor openings or cracks in the flooring, it is also advisable to make certain that there are no highly combustible materials on the floor below, where they would be exposed to sparks which might drop through the floor.

Watch the sparks and hot slag. See that they do not come in contact with combustible material, do not lodge in floor cracks, and do not drop through holes to the floor below. Use sheet-metal guards or asbestos curtains where needed. Make sure that the guards and curtains are adequate. Because hot slag may roll along the floor for considerable distances, it is important when using asbestos blankets as a curtain that no openings exist where the curtain meets the floor.

Avoid the use of tarpaulins as experience has shown that they do not provide adequate protection.

Station extra men with small hose, chemical extinguishers or fire pails nearby when the nature of the work requires that blowpipes be used near wooden construction or in locations where the combustible material cannot be removed. In sprinklered buildings, *maintain sprinkler protection without interruption while cutting blowpipes are being used.*

Keep a man at the scene of the work for a half hour after completion to make sure that sparks have not started smoldering fires.

J-22. Dusty and gassy atmospheres in certain mines, mills, industrial plants, and plants spraying lacquers and the like require extra precautions to avoid explosions or fires from electric sparks, matches and open fires. Welding or cutting in such suspicious places should therefore de done only when proper precautions have been taken and only after the responsible official in charge has inspected the situation and has personally given instructions to proceed.

## STOPPING WORK

J-23. When the welding or cutting is to be stopped for a few minutes, release the pressure adjusting screws of the regulators by turning them to the left.

J-24. When the welding or cutting is stopped for a longer period (during lunch hour or over night) close the cylinder valves and then release all gas pressure from the regulators by opening the blowpipe valves momentarily. Close the blowpipe valves and release the pressure adjusting screws. If the equipment is to be taken down, make certain that all gas pressures are released from the regulators and that the pressure adjusting screws are turned to the left until free.

## ACETYLENE GENERATORS

J-25. *Workmen in charge of acetylene generators, acetylene or oxygen piping systems, or oxygen or acetylene manifolds should be carefully instructed by*

*their superiors and judged competent for this important work before being left in charge. Printed rules and instructions covering the operation, maintenance and handling of acetylene generators are supplied by the manufacturers. Efficiency and safety require compliance with ALL instructions.*

## K. *General Maintenance Recommendations*

K-1. Equipment should be inspected at frequent intervals by a competent operator. Where apparatus has to be equipped with a replacement part, only such parts as are supplied by the manufacturer should be used.

K-2. Do not use blowpipes or regulators which are in need of repair. regulators

### BLOWPIPE MAINTENANCE

K-3. If leakage develops around the blowpipe valve stems, tighten the packing nuts, and if necessary, repack. Use only packing supplied by or recommended by the manufacturer of the blowpipe. Be certain to *use no oil.*

K-4. If a blowpipe valve does not shut off completely, remove the valve assembly and with a clean rag wipe the seating portion of the valve stem, and of the body or replaceable seat. If the valve still leaks, new parts should be used, or the valve body should be re-seated.

K-5. If the orifices in the blowpipe tips or nozzles become clogged, clean them with the proper size drill or a soft copper or brass wire. A sharp hard tool which would enlarge or bellmouth the orifices, must not be used. *Clean the orifices from the inner end wherever possible.*

K-6. If the blowpipe passages become clogged these can be cleared by blowing oxygen backward through the blowpipe. To do so, remove both lengths of hose from the blowpipe, put in the largest size welding head, tip or nozzle, hold the oxygen hose over the end of the tip, set the oxygen regulator at about 20 lb. per sq. in. pressure, and blow oxygen backward through the blow-

pipe, first with only the acetylene valve open and then with only the oxygen valve open. (Note: This specialized purpose and the one described in Recommendation D-4, page 302, are the only exceptions to the universal rule that oxygen should not be used as a source of pressure or a cleaning jet. Oxygen is preferred for cleaning blowpipe passages at the rare intervals when this is needed because ordinary compressed air contains considerable oil and moisture. Be sure all hose is disconnected from the blowpipe.)

K-7. A backfire or flashback (see Recommendations J-12 and J-13, page 308) may be caused by a loose tip or nozzle or by dirt on the seat. If the flame continues to snap out, or if there has been a flashback, first make certain that the welding head nut, detachable welding tip, or cutting nozzle nut is tight. Reasonable force may be used in tightening a welding tip or cutting nozzle, but only slight force should be necessary to tighten a welding head nut. If this fails to remedy the trouble, check the oxygen and acetylene pressures to make certain they are correct. Another check which can be made is to examine and wipe clean all seating surfaces of welding head, tip, or cutting nozzle, and the matching surfaces in the blowpipe. If these surfaces are damaged and fail to seat properly, they must be reseated with proper tools. It can be fairly certain that seating surfaces in the blowpipe are at fault if a new nozzle, welding head, or tip does not remedy the trouble.

## REGULATOR MAINTENANCE

K-8. If a regulator creeps—this will be indicated on the low (working) pressure gauge by pressure building up when the blowpipe valves are closed—have the regulator repaired at once.

K-9. If excessive pressure is allowed to enter the pressure gauge suddenly, the mechanism may be sprung and the hand will not go back to the pin when the pressure in the regulator is released. The gauge must then be returned to the manufacturer for repair, since it will

no longer indicate the correct pressure. This damage may be caused in the high pressure gauge by opening the cylinder valve too quickly and in the low pressure gauge by leaving the pressure adjusting screw turned in instead of releasing it (turning it counter-clockwise until loose) before the cylinder valve is opened.

K-10. When regulators are to be out of service for several weeks or longer, it is good practice to turn in the pressure adjusting screw just enough to relieve the pressure on the internal valve seat. This aids in lengthening the life of the seat, especially seats that are made of relatively soft materials.

## CYLINDER CONNECTIONS

K-11. A gas-tight connection must be maintained between the regulator and the cylinder. If the cylinder valve has not been cracked, that is, opened slightly for a moment before attaching the regulator, dirt may be left in it which might mar the regulator inlet nipple seat, or prevent a gas-tight connection being made between the regulator and the cylinder valve. If the connection leaks when reasonable force has been used in tightening the nut, close the cylinder valve, take off the regulator and clean both the inside of the cylinder valve seat and the regulator inlet nipple seat. Never tighten a leaky connection between regulator and cylinder without first closing the cylinder valve. If excessive force is used in tightening the connections, the seats may be marred and the thread in the nut become so distorted that it will not fit any other cylinder.

## HOSE MAINTENANCE

K-12. All hose should be examined carefully at least once every week for leaks, worn places and loose connections. This can be done by immersing the hose in water when under normal working pressure. It is good practice, about every two months, to cut off the hose at each end about two inches back of the connection and reinsert connections securely.

K-13. Leaks should be repaired at once by cutting the hose and inserting a splice. Leaks not only waste acetylene and oxygen, but may become a source of hazard. Acetylene escaping from hose is liable to become ignited and start a fire or set fire to the operator's clothing.

K-14. Do not attempt to repair hose with tape.

K-15. Should a flashback occur and burn in the hose, discard that length of hose. A flashback of this sort renders a piece of hose unsafe because it burns the inner walls. Sooner or later this part of the hose will disintegrate and cause trouble by clogging or otherwise interfering with proper operation of the blowpipe.

## SUPPLEMENTARY READING

Safe Practices Bulletin No. 23, published by the National Safety Council, 20 N. Wacker Drive, Chicago, Ill.; Regulations of the National Board of Fire Underwriters for the Installation and Operation of Gas Systems for Welding and Cutting as recommended by the National Fire Protection Association, 60 Batterymarch St., Boston, Mass.; and the rules of the Compressed Gas Manufacturers' Association, 110 West 40th St., New York, N. Y., relating to the safe handling and use of cylinders of compressed gases, are suggested and recommended to the safety engineer as containing additional and authoritative information on the subject of safe practices.

CHAPTER 41

# Shop Layout and Organization

ALTHOUGH shop layout is determined to a large extent by local conditions, there are certain general principles that can be followed to advantage even in the smallest shops.

These principles have been applied in developing an ideal welding shop layout, shown in plan in Fig. 164. The arrangement with obvious modifications is suitable either for a contract welding shop, or for a central welding department in a plant, either large or small.

*General Accessories.* Considering first the welding room, it will be noted that most of the equipment is concentrated on one side of the shop. The smaller welding jobs can be done here; the other side of the shop being left clear for handling heavy work. A traveling hoist is mounted on an I-beam that runs the length of the building. It should be mounted high enough so a truck can be backed under it for loading and unloading.

Accessories provided in this complete shop include an air compressor, grinding wheel, drill press, anvil, a gas-fired preheating furnace and an annealing box. It goes without saying that there should also be an ample assortment of smaller machinist's and blacksmith's tools and the more strictly welding accessories mentioned in Chapter 6.

*Preheating Equipment.* Several hundred firebrick or dead-burned building brick should be available for temporary preheating furnaces for large castings. Second-hand brick in good condition will answer the purpose just as well as new ones. Brick should be kept in a dry place.

Provisions should be made for thorough ventilation. A hood and exhaust pipe should be built above the permanent preheating furnace. Roof ventilators should also be installed.

*Acetylene Generator.* The acetylene generator is housed quite separate on one side from the carbide storage room and the oxygen room on the other. The generator indicated on the

sketch is an Oxweld low-pressure duplex acetylene generator, which means that it has two generating compartments, so one may always be in operation even while the other is being flushed out and recharged.

Two pits are provided for the generator sludge. While one pit is in use, the residue is settling in the other. When thoroughly settled, the clear water is drawn off and the thick resi-

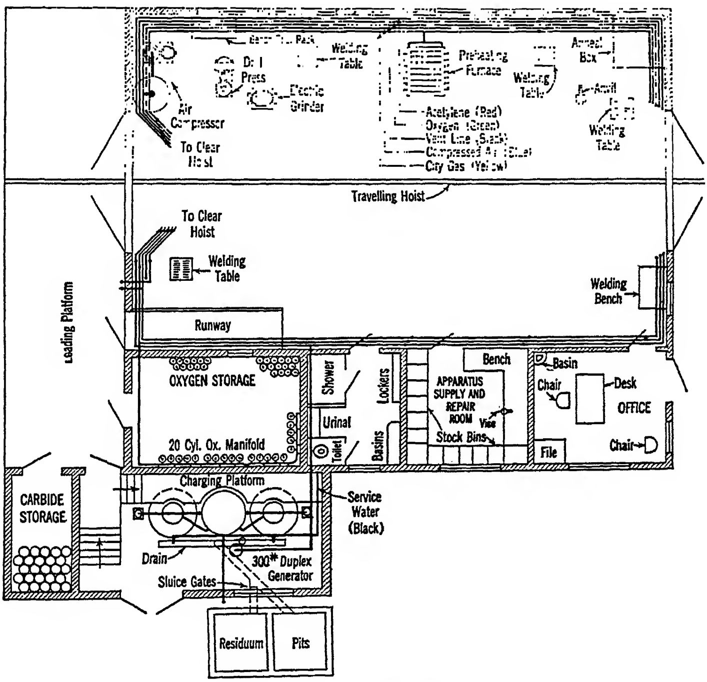



Fig. 164. Ideal welding shop layout.

due shoveled out. As this material is simply hydrated lime, it may be used advantageously in many ways around the plant or shop.

Obviously the size of the generator may vary, depending upon the amount of work being done simultaneously in the near vicinity.

*Piping System.* The various welding stations are supplied with oxygen and acetylene piped from a convenient point. This

system has many advantages. It permits the use of generated acetylene, which for work in the shop is usually more economical than acetylene in cylinders. It also eliminates the time lost by operators in handling oxygen and acetylene cylinders to their individual jobs.

In this shop layout oxygen is piped from a 20-cylinder manifold. In this the cylinders are divided into two independent units of 10 cylinders each so one set of ten is always connected to the line while the exhausted cylinders of the other unit are being replaced with full ones. The line pressure as set by the master regulator on the manifold should be sufficient to take care of the maximum working pressure required at any of the welding stations. Full cylinders of oxygen are stored on one side of the manifold; empties on the other. (Cylinders should be used as nearly as possible in order received, and empties returned promptly.)

Installation of piping for oxygen and acetylene should not be attempted without first consulting with the manufacturers of oxygen and of the acetylene generator. Their advice will assure an efficient system.

*Color Scheme.* The welding shop shown in the plan is also piped for compressed air for pneumatic tools and city gas for preheating furnaces. All these conveniences make quite a system of piping and it is advisable to use a distinguishing color scheme. The following is recommended.

| PIPING FOR | COLOR |
|---|---|
| Acetylene | Red |
| Oxygen | Green |
| City gas | Yellow |
| Compressed air | Blue |
| Vent line | Black |
| Service water | Gray |

Paint the entire line and valve boxes with the distinguishing color. Oxygen valves should not be painted—keep oil and grease away from oxygen.

*Regulators.* At each welding station, the branch from the oxygen line should have an oxygen station regulator and the acetylene branch should have a hydraulic back pressure valve. (Note: Where a pressure acetylene generator is installed an

acetylene station regulator must be used instead of the hydraulic valve.)

Hydraulic back pressure valves have a vent for removing any acetylene that may enter the valve under back pressure or reverse flow. The vents from each station valve are connected to a vent-pipe that leads outside the building above the roof level.

### SMALL WELDING SHOPS

For the smaller shops owning a single cutting and welding outfit, cylinders of oxygen and of acetylene are generally used instead of a piped supply. Cylinders should preferably be mounted on trucks holding one cylinder of oxygen and one of acetylene. With regulators, hose and blowpipe attached this makes a most convenient portable unit.

Cylinders with regulators and hose attached should always be fastened in some way so they cannot be accidently knocked over, breaking or damaging the regulators. If the cylinders are not mounted in a truck they should be chained to the wall or other firm support. Cylinders should always be standing upright when in use.

### SUPPLEMENTARY READING

Those in charge of welding shop layout and organization should read and follow the "Regulations of the National Board of Fire Underwriters for the Installation and Operation of Gas Systems for Welding and Cutting." Copies can be obtained from the National Fire Protection Association, 60 Batterymarch St., Boston, Mass.

## TIME AND MATERIAL FOR WELDING STEEL

| Thickness of Metal In. | Thickness of Metal Gauge | Gas Consumption: Oxygen Cu. Ft. Per Hr. | Gas Consumption: Acetylene Cu. Ft. Per Hr. | Speed Range * Linear Ft. Per Hr. | Iron Welding Rod ** Lb. Per Lin. Ft. |
|---|---|---|---|---|---|
| .. | 28 | 1.0— 2.0 | 0.93— 1.87 | 30 —40 | .......... |
| .. | 25 | 2.5— 4.5 | 2.34— 4.20 | 27 —36 | .......... |
| 1/32 | 22 | 3.5— 5.5 | 3.3 — 5.1 | 25 —32 | .......... |
| 1/16 | 16 | 5.0— 8.5 | 4.7 — 7.9 | 19 —29 | 0.01—0.05 |
| 3/32 | 13 | 7.0—11.0 | 6.5 —10.0 | 16 —23 | 0.02—0.07 |
| 1/8 | 11 | 9.0—14.0 | 8.4 —13.1 | 12 —20 | 0.04—0.09 |
| 3/16 | .. | 13.0—18.0 | 12.1 —16.8 | 7 —12½ | 0.08—0.18 |
| 1/4 | .. | 17.5—25.0 | 16.3 —23.4 | 5 — 9 | 0.15—0.28 |
| 3/8 | .. | 25.0—34.0 | 23.4 —31.8 | 3 — 6 | 0.30—0.75 |
| 1/2 | .. | 36.0—46.0 | 33.6 —43.0 | 2½— 4½ | 0.60—1.00 |
| 5/8 | .. | 43.0—56.0 | 40.0 —52.0 | 2 — 3 | 1.00—1.50 |
| 3/4 | .. | 53.0—67.0 | 49.5 —62.5 | 1½— 2½ | 1.40—2.30 |
| 1 | .. | 74.0—95.0 | 69.0 —88.0 | 1 — 2 | 2.40—4.00 |

* Lowest speeds are for short welds and inexperienced operators, highest speeds are for long welds and thoroughly experienced operators.

** The amount of welding rod required varies for the type and angle of vee and for the amount of reinforcement.

## TIME AND MATERIAL FOR CUTTING STEEL

| Thickness of Metal Inches | Linear Cutting Speed †: Machine Cutting In. Per Min. | Linear Cutting Speed †: Hand Cutting In. Per Min. | Gas Consumption Per Minute: Oxygen Cu. Ft. | Gas Consumption Per Minute: Acetylene Cu. Ft. | Gas Consumption Per Hour: Oxygen Cu. Ft. | Gas Consumption Per Hour: Acetylene Cu. Ft. |
|---|---|---|---|---|---|---|
| 1/8 | 22.6—32.0 | 19.9—29.8 | 0.8— 0.9 | 0.12—0.15 | 45— 55 | 7.2— 8.8 |
| 1/4 | 20.4—28.4 | 17.6—25.8 | 1.3— 1.6 | 0.15—0.18 | 77— 93 | 8.7—10.7 |
| 3/8 | 18.9—26.3 | 16.0—23.7 | 1.6— 1.9 | 0.16—0.20 | 95—115 | 9.7—11.9 |
| 1/2 | 17.6—24.6 | 14.8—22.2 | 1.8— 2.1 | 0.18—0.22 | 105—125 | 10.5—12.9 |
| 3/4 | 15.4—21.6 | 13.1—19.8 | 2.0— 2.4 | 0.20—0.24 | 117—143 | 12.0—14.6 |
| 1 | 13.6—19.4 | 11.8—18.0 | 2.2— 2.7 | 0.22—0.27 | 130—160 | 13.0—16.0 |
| 2 | 10.0—14.0 | 8.6—13.0 | 3.1— 3.8 | 0.27—0.33 | 185—225 | 16.2—19.8 |
| 3 | 7.8—10.9 | 6.6— 9.8 | 4.0— 4.8 | 0.31—0.38 | 240—290 | 18.5—22.7 |
| 4 | 6.4— 8.9 | 5.2— 7.8 | 4.9— 6.0 | 0.35—0.43 | 293—357 | 21.1—25.9 |
| 5 | 5.4— 7.4 | 4.2— 6.4 | 5.8— 7.1 | 0.40—0.49 | 347—423 | 23.9—29.3 |
| 6 | 4.7— 6.5 | 3.5— 5.4 | 6.7— 8.2 | 0.44—0.54 | 400—490 | 26.5—32.3 |
| 8 | 3.7— 4.9 | 2.6— 4.2 | 8.4—10.3 | 0.53—0.64 | 505—615 | 31.5—38.5 |
| 10 | 2.9— 3.8 | 1.9— 3.2 | 10.2—12.5 | 0.62—0.75 | 610—750 | 36.9—45.1 |
| 12 | 2.4— 3.0 | 1.4— 2.6 | 12.0—14.7 | 0.71—0.86 | 720—880 | 42.3—51.7 |

† NOTE—Lowest speeds and highest gas consumption per linear foot are for inexperienced operators, short cuts, dirty or poor material.

Highest speeds and lowest gas consumption per linear foot are for thoroughly experienced operators, long cuts, clean and good material.

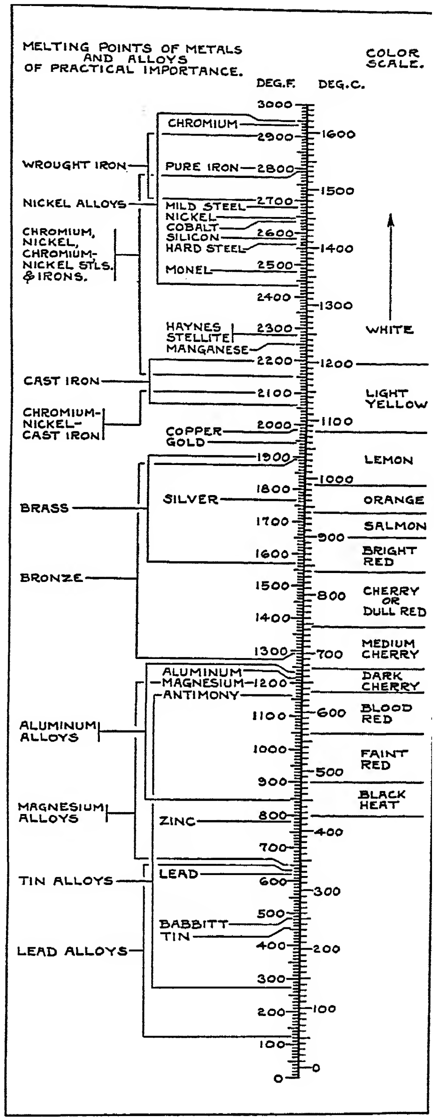
# TEMPERATURE DATA

## Conversion Data, Melting Points, and Temperature Colors

This Fahrenheit-Centigrade temperature chart will provide a ready means for converting temperatures from one scale to the other. It offers a good opportunity for presenting other information at the same time. The melting points of various metals and alloys that are of practical importance are shown to the left of the scale. On the right of the scale are shown the color designations that are commonly used in judging the temperatures of hot metal by color.

The melting points shown as single temperatures are for metals that are elements. Each group of alloys has a range of melting points due largely to the effect of even a small change in relative composition. The ranges shown are, however, indicative of the relationship in melting point between a metal and its alloys and between different groups of alloys.

The temperature color chart can, of course, merely suggest the relationship between heat colors of metals and temperatures. Observations should be made in the dark for best results.



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